



# A review of the potential neurological adverse events of COVID-19 vaccines

Zeinab Mohseni Afshar<sup>1</sup> · Akanksha Sharma<sup>2</sup> · Arefeh Babazadeh<sup>3</sup> · Ali Alizadeh-Khatir<sup>4</sup> · Terence T. Sio<sup>5</sup> · Mohamad Ali Taghizadeh Moghadam<sup>6</sup> · Ali Tavakoli Pirzaman<sup>7</sup> · Ahmadreza Mojada<sup>7</sup> · Rezvan Hosseinzadeh<sup>7</sup> · Mohammad Barary<sup>8,9</sup> · Soheil Ebrahimpour<sup>3</sup>

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## Abstract

Despite the advantages of getting access to the coronavirus disease 2019 (COVID-19) vaccines, their potential ability to induce severe adverse events (AEs) has been a significant concern. Neurological complications are significant among the various adverse events following immunization (AEFI) due to their likely durability and debilitating sequelae. Neurological AEs following COVID-19 vaccination can either exacerbate or induce new-onset neuro-immunologic diseases, such as myasthenia gravis (MG) and Guillain–Barre syndrome (GBS). The more severe spectrum of AEs post-COVID19 vaccines has included seizures, reactivation of the varicella-zoster virus, strokes, GBS, Bell’s palsy, transverse myelitis (TM), and acute disseminated encephalomyelitis (ADEM). Here, we discuss each of these neurological adverse effects separately.

**Keywords** COVID-19 · Vaccine · Adverse event · Neurologic · SARS-CoV-2

## Introduction

Despite the advantages of getting access to the coronavirus disease 2019 (COVID-19) vaccines, their potential ability to induce severe adverse events (AEs) has been a significant concern. Neurological complications are significant among the various adverse events following immunization (AEFI) due to their likely durability and debilitating sequelae [1, 2]. Neurological AEs following COVID-19 vaccination can either exacerbate or induce new-onset neuro-immunologic diseases, such as myasthenia gravis (MG),

and Guillain–Barre syndrome (GBS) [3–5]. In addition, after vaccination, hypercoagulability and a pro-thrombotic state may further increase cerebrovascular events [6, 7]. The Centers for Disease Control (CDC) Vaccine Adverse Event Reporting System (VAERS) has announced several neurological complications following COVID-19 vaccines [8]. The most common neurological symptoms following COVID-19 vaccines have included headache, anosmia, dysgeusia, myalgia, paresthesia, weakness, and dizziness [9]. Several rare side effects, including tremor, diplopia, tinnitus, dysphonia, delirium, and syncope, have also been observed

✉ Mohammad Barary  
m.barary@mubabol.ac.ir

✉ Soheil Ebrahimpour  
drsoheil1503@yahoo.com

<sup>1</sup> Clinical Research Development Center, Imam Reza Hospital, Kermanshah University of Medical Sciences, Kermanshah, Iran

<sup>2</sup> Department of Neurology, Mayo Clinic, Scottsdale, AZ, USA

<sup>3</sup> Infectious Diseases and Tropical Medicine Research Center, Health Research Institute, Babol University of Medical Sciences, Babol, Iran

<sup>4</sup> Mobility Impairment Research Center, Health Research Institute, Babol University of Medical Sciences, Babol, Iran

<sup>5</sup> Department of Radiation Oncology, Mayo Clinic, Scottsdale, AZ, USA

<sup>6</sup> Student Research Committee, Shiraz University of Medical Sciences, Shiraz, Iran

<sup>7</sup> Student Research Committee, Babol University of Medical Sciences, Babol, Iran

<sup>8</sup> Student Research Committee, Virtual School of Medical Education and Management, Shahid Beheshti University of Medical Sciences, Tehran, Iran

<sup>9</sup> Students’ Scientific Research Center (SSRC), Tehran University of Medical Sciences, Tehran, Iran

that are significant to note [10, 11]. The more severe spectrum of AEs post-COVID-19 vaccines has included seizures, reactivation of the varicella-zoster virus, strokes, GBS, Bell's palsy, transverse myelitis (TM), and acute disseminated encephalomyelitis (ADEM). Here, we discuss each of these neurological adverse effects separately.

## Bells palsy

Bell's palsy (BP), known as idiopathic facial paralysis, is an acute unilateral peripheral facial nerve palsy [12]. This condition is, in fact, an idiopathic facial palsy of spontaneous origin, although a causal association with the herpes simplex virus has been considered [13]. However, in the current pandemic, studies revealed abundant cases of BP following SARS-CoV-2 infection [14–16]. Several vaccines, including influenza, hepatitis B, and meningococcal conjugate vaccines, have been associated with BP [17–19]. With the development of COVID-19 vaccines, significant concerns have arisen about their potential to trigger the onset of Bell's palsy. Despite being less prevalent than expected, this complication has still been abundantly reported following these vaccines [12, 20, 21]. Nonetheless, the US Food and Drug Administration (FDA) announced that the frequency of Bell's palsy cases following vaccination is not more unusual than in the general population [22]. Despite the inability to confirm the causal relationship between the vaccines and this complication, the timing of onset following vaccination can suggest the association. Confirmation would need to be studied in larger populations [23]. This reaction could be either immune-mediated or induced by viral reactivation [24], but the latter does not seem valid for COVID-19 vaccines since no live attenuated COVID-19 vaccine platform has yet been introduced.

The immune-mediated mechanism for this complication is thought to be through host molecules' mimicry of the vaccine's antigens or by eliciting a type I interferons response [25, 26]. The timing of BP onset in relationship to vaccination is unclear, although most of the cases have occurred in an average 4-week interval after vaccination [27]. Moreover, there has been a case of sequential contralateral facial nerve palsies following each dose of COVID-19 vaccines reported recently [27]. Up to now, BP has been reported following various COVID-19 vaccine types, including Pfizer-BioNTech, Janssen, CoronaVac, Moderna, and Oxford-AstraZeneca vaccines [12, 23, 28–30]. Nonetheless, the risk of developing facial nerve palsy has been estimated to be higher with mRNA vaccines than with other vaccine platforms; this fact can help us decide the choice of COVID-19 vaccine in individuals with a history of BP [31]. It is vital to note that most cases of BP, regardless of etiology, are self-limiting and subside within a few months [32]. However, antiviral

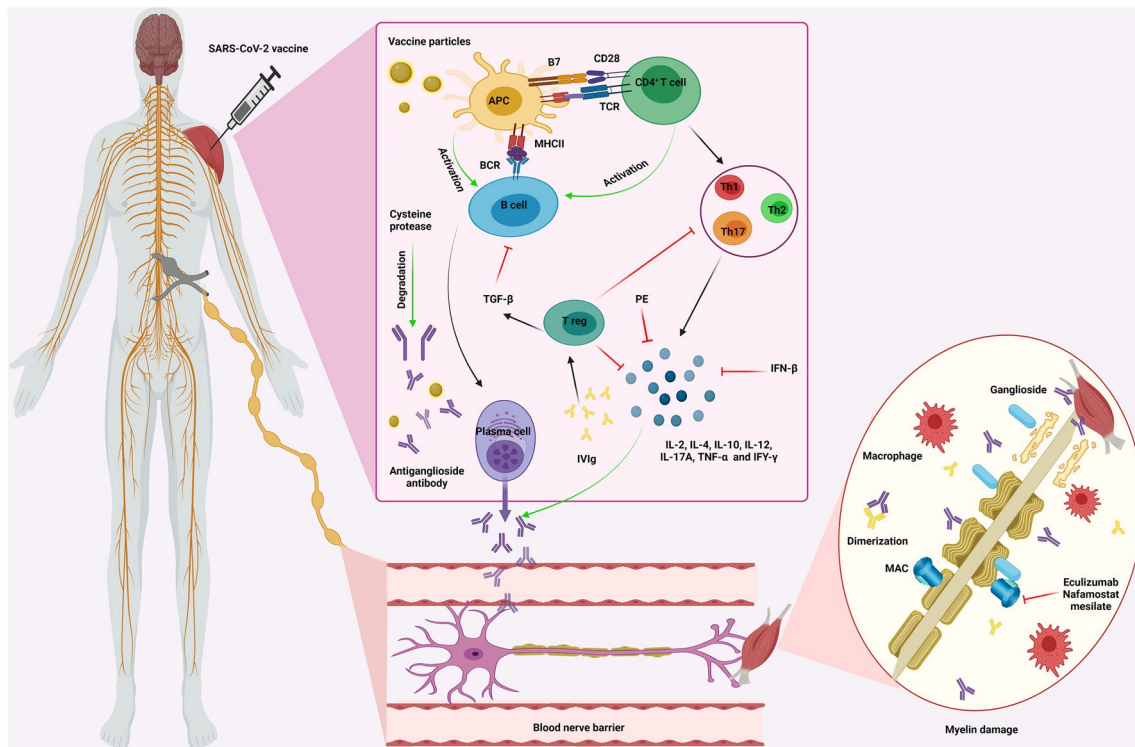
agents and steroids are frequently tried as a treatment and hasten recovery [32].

## Guillain–Barré Syndrome

Guillain–Barré Syndrome (GBS) is defined as an inflammatory ascending polyradiculoneuropathy. The underlying triggers for this neurological disorder include infections and vaccines on an autoimmune basis [33] (Fig. 1). The introduction of COVID vaccines has arisen the concerns of developing GBS following vaccination [34] since GBS had been previously observed in individuals who received the meningococcal, tetanus-toxoid, human papillomavirus (HPV), and most prominently, the influenza vaccines [35–39]. This complication has been reported following Pfizer-BioNTech, Johnson & Johnson, and ChAdOx1 nCoV-19 COVID-19 vaccines [1, 40–42]. Moreover, one case of isolated bilateral facial diplegia with paresthesias (BFP), an uncommon variant of GBS, has been reported following the Janssen COVID-19 vaccination [43]. It is believed that vaccine-induced immune responses may trigger autoimmune reactions, resulting in autoantibody production against myelin, resulting in GBS [40]. The diagnosis of vaccine-induced GBS is the same as that of other causes, through clinical and paraclinical findings such as cerebrospinal fluid (CSF) analysis and electromyography and nerve conduction velocity (EMG/NCV) studies, in addition to considering the temporal relationship between the event and vaccination [44]. Intravenous immune globulin (IVIg) (0.4 g per kg body weight every day for 5 days) and plasma exchange (200–250 ml plasma kg body weight in 5 sessions) can be considered as efficient treatments for GBS [45].

## Transverse myelitis

Transverse myelitis (TM) is a condition where spinal cord segments may become inflamed, resulting in significant motor, autonomic and sensory deficits. [46]. Since the beginning of the current pandemic, several cases of TM have been reported in SARS-CoV-2-infected patients [47, 48]. Apart from infections as a cause of TM, vaccines are of great importance in the evolution of this neurological condition [49]. TM following vaccination had previously been observed with various vaccines, including tetanus, measles–mumps–rubella, influenza (H1N1), hepatitis B, polio, and Japanese B encephalitis vaccines [50–54]. This neurological complication has also been reported following COVID-19 vaccination with viral vector-based and mRNA-based COVID-19 vaccines. However, their association has not been confirmed in a number of trials [2, 55–57]. Moreover, a rare subtype of TM, known as longitudinally extensive transverse myelitis (LETM), has been reported following COVID-19 vaccination [58]. The pathophysiology of TM



**Fig. 1** COVID-19 vaccine-induced Guillain-Barré syndrome. After the administration of the COVID-19 vaccine, the vaccine particles enter the body and activate APCs, which could trigger B cells and CD4<sup>+</sup> T cells activation. Naïve CD4<sup>+</sup> T cells are then differentiated into three subgroups, Th<sub>1</sub>, Th<sub>2</sub>, and Th<sub>17</sub>, producing cytokines, such as IL-2, IL-4, IL-10, IL-12, IL-17A, TNF- $\alpha$ , and IFN- $\gamma$ . Moreover, B cells are converted to plasma cells, secreting antiganglioside antibodies. These antibodies are then gone through the blood-nerve barrier, binding to the ganglioside of the myelinated motor neurons or attaching to the neuromuscular junction. As a result of forming gangliosides-antiganglioside antibody complexes, MAC and macrophages are activated, attacking and destroying the myelin. Such demyelination would decrease the speed of action potential transmission through these nerves, causing an inflammatory ascending polyradiculoneuropathy. IVIg administration could reverse these mecha-

nisms via 2 main pathways: triggering Treg cells, inhibiting B cells and inflammatory cytokines, and dimerizing with antiganglioside antibodies. Moreover, plasmapheresis could alleviate the symptoms via actively depleting inflammatory cytokines from patients' bloodstream. Furthermore, cysteine proteases can degrade antiganglioside antibodies, inhibiting this inflammatory neuropathy. Eculizumab and nafamostat mesilate would also inhibit MAC, alleviating the demyelination. Abbreviations: APC Antigen-presenting cell, TCR T cell receptor, MHC II Major histocompatibility complex II, BCR B cell receptor, Th T helper cell, IL-2 Interleukin-2, IL-4 Interleukin-4, IL-10 Interleukin-10, IL-12 Interleukin-12, IL-17A Interleukin-17A, TNF- $\alpha$  Tumor necrosis factor- $\alpha$ , IFN- $\gamma$  Interferon- $\gamma$ , GBS Guillain-Barré syndrome, IVIg Intravenous immune globulin, Treg regulatory T cell, TGF- $\beta$  Transforming growth factor- $\beta$ , PP Plasmapheresis, IFN- $\beta$  Interferon- $\beta$ , MAC Membrane attack complex

in the settings of SARS-CoV-2 infection is thought to be either via direct viral neuro-invasion or immune-mediated, while the mechanism by which COVID-19 vaccines might trigger TM may be immune and inflammatory reactions [59, 60]. The diagnosis is made by typical clinical evidence of bilateral sensory, motor, or autonomic dysfunction with an established spinal cord defect origin in magnetic resonance imaging (MRI) [61]. Unfortunately, TM is a neurological condition with unfavorable outcomes [62]. Although there is insufficient evidence, high-dose IV methylprednisolone (1 g per day for 3–7 days) has to be started immediately for all TM cases to improve neurological function and accelerate recovery [63, 64]. In a case report study, a COVID-19 patient with acute TM treated with high-dose IV methylprednisolone (1 g daily for 3 days) showed improved neurological

symptoms immediately after receiving IV corticosteroid therapy [65].

### Cerebrovascular events

Since the beginning of the COVID-19 pandemic, a significant increase in stroke rates was observed, later discovered to be due to SARS-CoV-2 infection [66–68]. Although not as common as SARS-CoV-2 infection, COVID-19 vaccination is also suspected to increase the risk of cerebrovascular events [69]. It is unknown whether the cerebrovascular events, including ischemic/hemorrhagic strokes and cerebral venous sinus thrombosis, are related to COVID-19 vaccination. If they are related, it also remains unclear how the vaccines may contribute—by causing arterial hypertension,

worsening thrombocytopenia, or exacerbating a hypercoagulable state [70, 71]. Previously, a stroke took place following vaccination with various other vaccines, including diphtheria, measles–mumps–rubella, and influenza vaccines [72–74]. The probability and reports of systemic thrombotic thrombocytopenic events following COVID-19 vaccination have caused a great deal of concern and hesitancy worldwide [71]. The Oxford-AstraZeneca (ChAdOx1 nCoV-19) vaccine had been the most notorious for this complication that many countries suspended its use [75]. However, thrombotic events have not been uncommon following the Johnson & Johnson COVID-19 vaccine [76, 77]. Cerebrovascular events, including hemorrhagic and ischemic strokes, from venous and arterial etiologies and an increased thrombotic and embolic risk, have been noted [78–81]. There have been reports of thrombosis in the cortical veins, transverse sinus, sigmoid sinus, inferior sagittal sinus, the vein of Galen, and the straight sinus that have all presented with intracranial hemorrhage (ICH) and subarachnoid hemorrhage (SAH), shortly after COVID-19 vaccination [80–83].

However, we should take into account that individuals with risk factors of thromboembolic events, such as pregnancy, postpartum state, oral contraceptives use, surgery, trauma, immobilization, malignancies, and thrombophilic genetic or autoimmune conditions including anti-thrombin, protein C, and protein S deficiency, factor V Leiden mutation, antiphospholipid antibodies, and hyperhomocysteinemia, are more prone to vaccine-induced cerebrovascular complications [84–87]. It is important to note that anti-CXCL4 antibodies are responsible for most cases of vaccine-induced immune thrombotic thrombocytopenia (VITT); this is similar to what happens with heparin-induced thrombocytopenia (HIT) [71, 88]. Depending on which vessel is involved, clinical manifestations may range from a simple headache, nausea, vomiting, and diplopia to focal neurologic signs, altered consciousness, and coma. The diagnosis of cerebrovascular AEs is generally made with comprehensive imaging, including brain computed tomography (CT), venogram, angiography, and MRI [89]. Management of cerebrovascular events following vaccination is generally the same as with any other cause, with the goal being assessment and management of risk factors and secondary stroke prevention. Heparin and platelet transfusions should be avoided until VITT has been excluded [90, 91]. In cases of systemic thrombotic thrombocytopenic events, IVIg, high-dose glucocorticoids, and plasmapheresis are recommended when indicated to restore platelet counts and address the autoimmune phenomenon [79, 92].

## Encephalopathy

Acute encephalopathy has been attributed to various etiologies, including toxins, infections, and vaccines. One of

the most prevalent neurological sequelae of COVID-19 has been encephalopathy which presents with cognitive impairment, altered consciousness, and even seizures [93–96]. However, the condition has been observed much less frequently following COVID-19 vaccination [94, 97–100]. In the past, several cases of encephalopathy had been reported after various vaccines, including hepatitis B, rabies, pertussis, measles, influenza, and HPV vaccines [101–107]. The pathophysiologic mechanism for vaccine-induced acute disseminated encephalomyelitis (ADEM) seems to be the inflammatory cascade or the cytokine storm triggered by the production of spike protein from translated mRNA in the vaccines [108, 109]. The diagnosis of ADEM in the settings of COVID-19 vaccination is similar to that of other causes and is accomplished through clinical and cerebrospinal fluid (CSF) findings and imaging modalities such as brain MRI. The treatment consists of corticosteroids and sometimes IVIg and plasmapheresis [110]. Fortunately, ADEM has a favorable outcome if conservative support is satisfactory [111].

## New-onset seizures

The pathophysiologic mechanisms of seizures during a SARS-CoV-2 infection differ significantly from those following COVID-19 vaccination. In the former, specific antibiotic therapies, cerebral hypoxemia, acute renal failure, and electrolyte impairment can be the underlying reasons [112–114]. The latter can happen in the settings of vaccine-induced encephalopathy or venous occlusion [97]. Before the current pandemic, HPV and H1N1 vaccinations had been related to functional (non-epileptic) seizures, which were believed to be psychogenic attacks [115, 116]. The association of febrile seizure with the measles–mumps–rubella–varicella vaccine has long been well established [117]. It is unknown whether non-motor seizures are related to COVID-19 vaccines or only a coincidence [118]. Patients with a known history of epilepsy or prior history of seizures may have a decreased threshold in the post-vaccine period due to the symptoms and illness. Rare attacks have included new-onset refractory status epilepticus that require further assessment and follow-up [119]. The diagnosis is based on clinical history, physical examinations, brain imaging (CT scan and MRI), electroencephalography, and serum prolactin level measurement. There are a variety of antiepileptic drugs (Table 1) that can be administered as first-line monotherapy in adults with epilepsy [120].

## Varicella-zoster virus reactivation

Since the beginning of the COVID-19 pandemic, several cases of herpes zoster have been reported in SARS-CoV-2 infected patients, even in immunocompetent individuals



**Table 1** Summary of the proposed diagnosis and management of neurological adverse events following COVID-19 vaccination

Neurological adverse event	Diagnosis	Management
Bell's palsy	History and physical examination: Rapid-onset (less than 72 h) unilateral paralysis of the facial nerve (weakness or complete loss of movement) with no defined reason	Oral corticosteroids (prednisolone) and antiviral agents (acyclovir and valacyclovir)
Guillain–Barré Syndrome	Clinical and paraclinical findings such as cerebrospinal fluid (CSF) analysis and electromyography and nerve conduction velocity (EMG/NCV) studies, in addition to considering the temporal relationship between the event and vaccination	IVIg (0.4 g per kg body weight every day for 5 days) and plasma exchange (200–250 mL plasma per kg body weight in 5 sessions) are similarly efficient remedies for GBS
Transverse myelitis	Typical clinical evidence of bilateral sensory, motor, or autonomic dysfunction with an established spinal cord defect origin in magnetic resonance imaging (MRI)	High-dose IV methylprednisolone (1 g daily for 3–7 days)
Cerebrovascular events	Brain computed tomography (CT), venogram, angiography, and MRI	IVIg High-dose glucocorticoids Plasmapheresis Non-heparin anticoagulants (like fondaparinux and argatroban)
Encephalopathy	Clinical and cerebrospinal fluid (CSF) findings and imaging modalities such as brain MRI	Corticosteroids and sometimes IVIg and plasmapheresis
New-onset seizures	Clinical history, physical examinations, brain imaging (CT scan and MRI), electroencephalography, and serum prolactin level measurement	Narrow-spectrum drugs (focal seizure) Carbamazepine Eslicarbazepine Gabapentin Lacosamide Oxcarbazepine Phenytoin Broad-spectrum drugs (focal and almost all generalized seizures) Lamotrigine Levetiracetam Topiramate Valproate Zonisamide
Myasthenia gravis exacerbation	Suspected through compatible signs and symptoms of fatigable muscle weakness and confirmed by EMG studies, pharmacologic testing, and serum Ab assay	Pyridostigmine (30 mg 3–4 times a day, then can be increased to 60 mg 4 times a day) Oral prednisone (0.75–1 mg per kg daily) Azathioprine Cyclosporine Tacrolimus Rituximab
Varicella-zoster virus reactivation	Clinical manifestations (dermatomal rash, pain, paresthesia, dysesthesia, allodynia, pruritus), IF test for VZV antigen, PCR test for VZV DNA	Acyclovir (800 mg orally 5 times a day for 7–10 days) Valacyclovir (1 g orally 3 times a day for 7 days) Famciclovir (500 mg orally 3 times a day for 7 days)

[121, 122]. The potential mechanism for this event is suggested to be COVID-19-induced lymphopenia and CD4<sup>+</sup> T cell dysfunction [123]. Nonetheless, immunomodulation, immune dysregulation, and attenuated alloreactivity are believed to be the underlying pathophysiology for vaccine-induced herpes zoster reactivation [124, 125]. Herpes zoster reactivation was previously reported following yellow fever, influenza, hepatitis A, and rabies vaccines [126, 127]. Up to the present time, this neurological complication has been reported following various COVID-19 vaccines, including mRNA-based (Pfizer-BioNTech, Moderna), viral vector (Oxford ChAdOx1-S or AZD1222), and inactivated

vaccines (COVAXIN) [125, 128–133]. Moreover, a case of varicella-zoster virus-induced small vessel vasculitis following the first dose of the Pfizer-BioNTech COVID-19 vaccine has been reported [134]. It should be noted that in all suspected cases of vaccine-induced herpes zoster reactivation, a de novo SARS-CoV-2 infection should be ruled out. The diagnosis is made with clinical manifestations (dermatomal rash, pain, paresthesia, dysesthesia, allodynia, and pruritus), immunofluorescence (IF) test for VZV antigen, and PCR test for VZV DNA. acyclovir, valacyclovir, and famciclovir (guanosine analogs) are recommended for VZV treatment [135].

**Table 2** Summary of the reported cases of neurological adverse events following SARS-CoV-2 infection vs post-COVID-19 vaccination

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
1	Alshar et al. [144]/2021	Bell's palsy	F/64	Iran	Left side facial nerve palsy	History and physical examination, brain CT scan and MRI, pulmonary CT scan, RT-PCR for SARS-CoV-2, and anti-SARS-CoV-2 IgM test	lopinavir/ritonavir (Kaletra) + dexamethasone	Associated with COVID-19 infection
2	Dahl et al. [145]/2021	Bell's palsy	M/37	Norway	Right side facial nerve palsy	History and physical examination, cerebral CT scan, spinal fluid examination, spinal fluid PCR, anti-SARS-CoV-2 IgG antibodies test	–	Associated with COVID-19 infection
3	Bastola et al. [146]/2021	Bell's palsy	M/48	India	Left side facial nerve palsy	History and physical examination, chest HRCT and PCR for SARS-CoV-2	Prednisolone	Associated with COVID-19 infection
4	Al-Mashdali et al. [147]/2021	Bell's palsy	M/21	Qatar	Right side facial nerve palsy	History and physical examination, chest CT scan and RT-PCR for SARS-CoV-2	Prednisolone and eye lubricant	Associated with COVID-19 infection
5	Hasibi et al. [148]/2021	Bell's palsy	M/52	Iran	Right side facial nerve palsy	History and physical examination, RT-PCR for SARS-CoV-2 and spiral chest CT scan	Prednisolone and favipiravir Then: remdesivir and IV dexamethasone	Associated with COVID-19 infection
6	Ferreira et al. [149]/2022	Bell's palsy	M/11	Portugal	Right side peripheral facial paralysis	History and physical examination, PCR for SARS-CoV-2, cranial CT, and MRI	Prednisolone	Associated with COVID-19 infection
7	Iacono et al. [150]/2022	Bell's palsy	M/5	Italy	Right side facial nerve palsy	History and physical examination, brain MRI and serological tests for SARS-CoV-2	Prednisolone and eye lubricant	Associated with COVID-19 infection

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
8	Kaplan[151]/2021	Bell's palsy	F/48	USA	Left side facial nerve palsy	History and physical examination, PCR for SARS-CoV-2 and chest CT scan	Prednisone, valacyclovir, and doxycycline (the doxycycline was discontinued after Lyme disease titers became negative)	Associated with COVID-19 infection
9	Szewczyk et al. [152]/2021	Bilateral facial nerve palsy	M/70	Poland	Bilateral facial nerve palsy	History and physical examination, brain CT scan and MRI and serological tests for SARS-CoV-2	Intravenous immunoglobulins (IVIg)	Associated with COVID-19 infection
10	Kumar et al. [153]/2021	Bell's palsy	F/28	India	Right side lower motor neuron facial nerve palsy	History and physical examination, RT-PCR for SARS-CoV-2	Prednisone and valacyclovir	Associated with COVID-19 infection
11	Neo et al. [154]/2021	Bell's palsy	M/25	Singapore	Left side facial weakness/palsy	History and physical examination, RT-PCR for SARS-CoV-2, and serological tests for SARS-CoV-2	Oral corticosteroids, valacyclovir, and eye care advice	Associated with COVID-19 infection
12	Neo et al. [154]/2021	Bell's palsy	M/34	Singapore	Right side facial weakness	History and physical examination, RT-PCR for SARS-CoV-2, and serological tests for SARS-CoV-2	Oral corticosteroids, valacyclovir, and eye care advice	Associated with COVID-19 infection
13	Khajia et al. [155]/2020	Guillain-Barré Syndrome and Bell's Palsy	M,44	USA	Bilateral facial weakness	History and physical examination, RT-PCR for SARS-CoV-2, serological tests for SARS-CoV-2, and brain MRI	IVIg	Associated with COVID-19 infection

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
14	Theophanous et al. [156]/2021	Bell's palsy	M/6	USA	Right side facial nerve palsy	History and physical examination, RT-PCR for SARS-CoV-2	IV acyclovir and IV Ig infusion (because of agammaglobulinemia) Then discharged with prednisolone and acyclovir	Associated with COVID-19 infection
15	Wan et al. [157]/2020	Bell's palsy	F/65	China	Left side facial nerve palsy	History and physical examination, RT-PCR for SARS-CoV-2, and brain MRI	Arbidol and ribavirin	Associated with COVID-19 infection
16	Bohania et al. [158]/2021	Bell's palsy	F/18	–	Right side facial nerve palsy	History and physical examination, COVID-19 antigen testing	Steroids, eye taping during sleep, and methylcellulose eye drops	Associated with COVID-19 infection
17	Burrows et al. [159]/2021	Bell's palsy	M/61	UK	Right side lower motor neuron facial palsy	History and physical examination and head CT scan	Prednisolone	Associated with COVID-19 vaccination (Pfizer-BioNTech)
18	Cellina et al. [160]/2022	Bell's palsy	F/35	Italy	Left side facial nerve palsy	History and physical examination and brain MRI	Prednisone	Associated with COVID-19 vaccination (Moderna)
19	Iftikhar et al. [162]/2021	Bell's palsy	M/36	Qatar	Left side facial nerve palsy + left upper limb numbness and weakness	History and physical examination, brain CT scan, and MRI	Prednisolone and eye lubricant	Associated with COVID-19 vaccination (Moderna)
20	Mussatto et al. [161]/2022	Bell's palsy (he was also a 20-year-prior case of HIV)	M/60	USA	Left side facial nerve palsy	History and physical examination	Prednisone and valacyclovir	Associated with COVID-19 vaccination (Pfizer-BioNTech)
21	Repajic et al. [28]/2021	Bell's palsy	F/57	USA	Left side facial nerve palsy	History and physical examination	Prednisone and an antiviral agent	Associated with COVID-19 vaccination (Pfizer-BioNTech)



Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
22	Yu et al. [162]/2021	Bell's palsy	F/36	China	Right side facial nerve palsy	History and physical examination, serological tests for SARS-CoV-2, and brain CT scan	Prednisone and artificial tear	Associated with COVID-19 vaccination (Sinovac Life Sciences inactivated COVID-19 vaccine)
23	Mason et al. [163]/2021	Bell's palsy	F/35	USA	Bilateral facial nerve palsy	History and physical examination, brain MRI and CT angiography	Methylprednisolone (IV) and acyclovir	Associated with COVID-19 vaccination (Moderna)
24	Mirmosayyeb et al. [164]/2022	Bell's palsy	F/27	Iran	Left side facial nerve palsy	History and physical examination and brain MRI	Prednisone and valacyclovir	Associated with COVID-19 vaccination (Russian Sputnik V)
25	Mirmosayyeb et al. [164]/2022	Bell's palsy	M/58	Iran	Left side facial nerve palsy	History and physical examination	Prednisone and valacyclovir	Associated with COVID-19 vaccination (Russian Sputnik V)
26	Pothiwala [165]/2021	Bell's palsy	M/46	Singapore	Right side facial nerve palsy	History and physical examination	Prednisone and acyclovir	Associated with COVID-19 vaccination (Moderna)
27	Kundi et al. [166]/2022	Bell's palsy	F/66	USA	Right side facial nerve palsy	History and physical examination and brain CT	Prednisone, acyclovir, meclizine, and ondansetron	Associated with COVID-19 vaccination (Ad26.COV2.S vaccine)
28	Nishizawa et al. [167]/2021	Bell's palsy	F/62	Japan	Right side facial nerve palsy	History and physical examination, head CT and brain MRI	–	Associated with COVID-19 vaccination (Ad26.COV2.S vaccine)
29	Colella et al. [20]/2021	Bell's palsy	M/37	Italy	Left side facial nerve palsy	History and physical examination	Prednisone and artificial tear	Associated with COVID-19 vaccination (Pfizer-BioNTech)
30	Martin-Villares et al. [168]/2022	Bell's palsy	F/34	Spain	Right side facial nerve palsy	History and physical examination and brain MRI	–	Associated with COVID-19 vaccination (Moderna)

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
31	Scheidl et al. [169]/2020	Guillain-Barré Syndrome	F/54	Germany	Acute, proximally pronounced, moderate, symmetric paraparesis, areflexia, numbness, and tingling of all extremities	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis and EMG and NCV studies)	IVIg (0.4 g per kg body weight every day for 5 days)	Associated with COVID-19 infection
32	Bueso et al. [170]/2021	Guillain-Barré Syndrome	F/60	USA	Symmetrical weakness of both the lower and upper extremities	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis)	IVIg (0.4 g per kg body weight every day for 5 days)+enoxaparin 30 mg twice a day	Associated with COVID-19 infection
33	Sedaghat and Karimi [171]/2020	Guillain-Barré Syndrome	M/65	Iran	Acute progressive weakness of distal lower extremities, quadriplegia, and bilateral facial paresis	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis and EMG and NCV studies)	IVIg (0.4 g per kg body weight every day for 5 days)	Associated with COVID-19 infection
34	Agosti et al. [172]/2021	Guillain-Barré Syndrome	M/68	Italy	Acute progressive symmetric ascending flaccid tetraparesis, bifacial nerve palsy, and muscular weakness	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis and NCV studies)	IVIg (0.4 g per kg body weight every day for 5 days)	Associated with COVID-19 infection
35	Paybast et al. [173]/2020	Guillain-Barré Syndrome	M/38	Iran	Acute symmetric progressive ascending paresthesia of both lower and upper extremities and bilateral facial droop	clinical and paraclinical findings (such as CSF analysis and EMG and NCV studies)	Therapeutic plasma exchange for 5 sessions	Associated with COVID-19 infection
36	Paybast et al. [173]/2020	Guillain-Barré Syndrome	F/14	Iran	Progressive ascending quadriparesis and mild lower limb weakness	Clinical and paraclinical findings (such as CSF analysis)	IVIg (20 g daily for 5 d)	Associated with COVID-19 infection

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
37	Dufour et al. [174]/2021	Guillain-Barré Syndrome	F/36	USA	Progressive ascending weakness	RT-PCR for SARS-CoV-2, history and physical examinations	IVIg (0.4 g per kg body weight every day for 5 days)	Associated with COVID-19 infection
38	Toscano et al. [175]/2020	Guillain-Barré Syndrome	–	Italy	Flaccid areflexic tetraplegia evolving to facial weakness, upper-limb paresthesia	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis and head and spine MRI)	2 IVIg cycles	Associated with COVID-19 infection
39	Toscano et al. [175]/2020	Guillain-Barré Syndrome	–	Italy	Facial diplegia and generalized areflexia evolving to paresthesia of lower limbs with ataxia	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis and head and spine MRI)	IVIg	Associated with COVID-19 infection
40	Toscano et al. [175]/2020	Guillain-Barré Syndrome	–	Italy	Flaccid tetraparesis and facial weakness evolving to areflexia	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis and head and spine MRI)	2 IVIg cycles	Associated with COVID-19 infection
41	Toscano et al. [175]/2020	Guillain-Barré Syndrome	–	Italy	Flaccid areflexic tetraparesis and ataxia	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis and head and spine MRI)	IVIg	Associated with COVID-19 infection
42	Toscano et al. [175]/2020	Guillain-Barré Syndrome	–	Italy	Facial weakness, flaccid areflexic paraplegia	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis and head and spine MRI)	IVIg and plasma exchange	Associated with COVID-19 infection

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
43	Ej Ormani et al. [176]/2020	A subtype of GBS: Acute Motor and Sensory Axonal Neuropathy (AMSAN)	F/70	Morocco	Bilateral weakness and paresthesia in all four extremities	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis and EMG and NCV studies)	IVIg (2 g/kg for 5 days), Hydroxychloroquine (600 mg/day), and Azithromycin (500 mg on the first day, then 250 mg/day)	Associated with COVID-19 infection
44	Khan et al. [177]/2021	Guillain-Barré Syndrome	M/27	India	Myalgia, weakness of the lower limb (then it involved the upper limb), and generalized hypotonia	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis and NCV studies)	IVIg (0.4 g per kg body weight every day for 5 days)	Associated with COVID-19 infection
45	Khan et al. [177]/2021	Guillain-Barré Syndrome	F/35	India	Paresthesia in both lower limbs followed by mild weakness	COVID-19 testing (she was positive for COVID-19), clinical and paraclinical findings (such as CSF analysis and NCV studies)	Managed as a case of COVID-19 (Supportive)	Associated with COVID-19 infection
46	Khan et al. [177]/2021	Guillain-Barré Syndrome	F/40	India	Lower-limb paresthesia is associated with weakness rapidly progressing from lower to upper limbs, respiratory muscles weakness	Clinical and paraclinical findings (such as CSF analysis and NCV studies)	IVIg (0.4 g per kg body weight every day for 5 days)	Associated with COVID-19 infection
47	Khan et al. [177]/2021	Guillain-Barré Syndrome	F/48	India	Paresthesia in both lower limbs and weakness	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis and NCV studies)	IVIg (0.4 g per kg body weight every day for 5 days)	Associated with COVID-19 infection

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
48	Khan et al. [177]/2021	Guillain-Barré Syndrome	M/50	India	Paresthesia in both lower limbs (then it involved upper limbs) and weakness	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis)	IVIg (0.4 g per kg body weight every day for 5 days)	Associated with COVID-19 infection
49	Su et al. [178]/2020	Guillain-Barré Syndrome with dysautonomia	M/72	USA	Symmetric paresthesias and ascending appendicular weakness	SARS-CoV-2 PCR, clinical and paraclinical findings (such as CSF analysis and EMG and NCV studies)	IVIg (2 g/kg between days 3 and 6)	Associated with COVID-19 infection
50	Darvishi et al. [179]/2021	Guillain-Barré Syndrome	M/56	Iran	Subacute progressive lower limbs weakness, paresthesia, and pain (then it progressed to severe, flaccid paraparesis)	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis)	IVIg (0.5 g/kg/d for 5 days)	Associated with COVID-19 infection
51	Zhao et al. [180]/2020	Guillain-Barré Syndrome	F/61	China	Symmetric weakness and areflexia in both lower limbs	RT-PCR for SARS-CoV-2, clinical and paraclinical findings (such as CSF analysis and NCV studies)	IVIg	Associated with COVID-19 infection
52	Mackenzie et al. [181]/2021	Guillain-Barré Syndrome	F/39	Colombia	Progressive generalized weakness of lower limbs	SARS-CoV-2 PCR, clinical and paraclinical findings (such as CSF analysis and EMG and NCV studies)	Supportive care, enoxaparin, losartan, meperidine IV for muscle pain, hydroxychloroquine, and dexamethasone	Associated with COVID-19 infection

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
53	Mostel et al. [182]/2021	Guillain-Barré Syndrome	F/69	USA	Progressive motor weakness and sensation loss in extremities, numbness and paresthesia in the right hand and leg, numbness and paresthesia in the left limb	SARS-CoV-2 antibodies, clinical and paraclinical findings (such as EMG studies)	IVIg (2 g/kg for 5 days)	Associated with COVID-19 infection
54	Farzi et al. [183]/2020	Guillain-Barré Syndrome	M/41	Iran	Ascending paresthesia and paralysis	SARS-CoV-2 PCR, clinical and paraclinical findings (such as EMG and NCV studies)	IVIg (0.4 g per kg body weight every day for 5 days)	Associated with COVID-19 infection
55	Nejad et al. [184]/2021	Guillain-Barré Syndrome	M/70	Iran	Symmetric weakness and areflexia in both lower limbs	SARS-CoV-2 PCR, clinical and paraclinical findings (such as CSF analysis)	IVIg	Associated with COVID-19 infection
56	McKean et al. [185]/2021	Guillain-Barré Syndrome	M/48	Malta	Bilateral facial weakness, ascending paraesthesia, and bilateral progressive lower limb weakness	Clinical and paraclinical findings (such as CSF analysis and NCV studies), brain CT and MRI	IVIg (2 g/kg for 5 days)	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
57	Hasan et al. [186]/2021	Guillain-Barré Syndrome	F/62	UK	Paraesthesia and progressive weakness of both lower limbs	Clinical and paraclinical findings (such as CSF analysis and NCV studies), brain CT and MRI	IVIg (2 g/kg for 5 days)	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
58	Allen et al. [187]/2021	Guillain-Barré Syndrome	M/54	UK	Bilateral facial weakness and distal dyesthesia in hands and feet	Clinical and paraclinical findings (such as CSF analysis and NCV studies), brain MRI	Oral prednisolone (60mg for 5 days)	Associated with COVID-19 vaccination (Oxford/Astrazeneca)



Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
59	Allen et al. [187]/2021	Guillain-Barré Syndrome	M/20	UK	Bilateral facial weakness and distal dysesthesia in feet	Clinical and paraclinical findings (such as CSF analysis and NCV studies), brain MRI	Oral prednisolone (60 mg for 5 days)	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
60	Allen et al. [187]/2021	Guillain-Barré Syndrome	M/57	UK	Dysarthria and facial weakness, distal dysesthesia in feet, and proximal leg weakness	Clinical and paraclinical findings (such as CSF analysis and NCV studies), and brain MRI	IV Ig	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
61	Allen et al. [187]/2021	Guillain-Barré Syndrome	M/55	UK	Bilateral thigh paresthesia, bilateral facial weakness	Clinical and paraclinical findings (such as CSF analysis) and brain MRI	No treatment	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
62	Min et al. [188]/2021	Sensory Guillain-Barré Syndrome	M/58	Republic of Korea	Severe paresthesia on both feet, mild hypoesthesia in vibration, temperature, and pain on both feet	SARS-CoV-2 PCR, Clinical and paraclinical findings (such as CSF analysis, NCV studies, and skin biopsy), and MRI	–	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
63	Min et al. [188]/2021	Sensory Guillain-Barré Syndrome	F/37	Republic of Korea	Paresthesia in both lower limbs	SARS-CoV-2 PCR, Clinical and paraclinical findings (such as CSF analysis, NCV studies, and skin biopsy), and MRI	–	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
64	Scendoni et al. [189]/2021	Guillain-Barré Syndrome	F/82	Italy	Progressively worsening of walking, weakness, lack of sensitivity in both lower limbs, and areflexia	Clinical and paraclinical findings (such as CSF analysis and EMG and NCV studies)	IV Ig (0.4 g per kg body weight every day for 5 days)	Associated with COVID-19 vaccination (Pfizer-BioNTech)

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
65	Maramattom et al. [190]/2021	Guillain-Barré Syndrome	F/43	India	Areflexic quadripareisis, facial diplegia, and respiratory failure	Clinical and para-clinical findings (such as CSF analysis and NCV studies)	IVIg	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
66	Maramattom et al. [190]/2021	Guillain-Barré Syndrome	F/67	India	Distal paraesthesia in all the extremities, bilateral facial weakness, dysphagia, and increasing limb weakness	–	IVIg and plasmapheresis	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
67	Maramattom et al. [190]/2021	Guillain-Barré Syndrome	F/53	India	Bilateral lower limb numbness and weakness, right-sided facial and tongue numbness (then it progressed to bilateral lower motor neuron facial palsy and Areflexic flaccid quadriplegia)	–	Mechanical ventilation	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
68	Introna et al. [191]/2021	Guillain-Barré Syndrome	M/62	Italy	Absent deep tendon reflexes, severe bilateral optic disk edema, progressively worsening sensory ataxia and ascending quadriparesis	Clinical and para-clinical findings (such as CSF analysis and EMG and NCV studies), brain CT and MRI	IVIg (2 g/kg for 5 days)	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
69	Razok et al. [192]/2021	Guillain-Barré Syndrome	M/73	Qatar	Progressive bilateral lower limb weakness	Clinical and para-clinical findings (such as CSF analysis and EMG and NCV studies), brain CT and MRI	IVIg (0.4 g per kg body weight every day for 5 days)	Associated with COVID-19 vaccination (Pfizer-BioNTech)

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
70	Rao et al. [193]/2021	Guillain-Barré Syndrome	F/42	USA	Progressive ascending weakness and paresthesias	Clinical and para-clinical findings (such as CSF analysis and NCV studies), brain and cervical MRI	IVIg (total of 2 g/kg in four divided doses)	Associated with COVID-19 vaccination (Pfizer-BioNTech)
71	Moreno-Escobar et al. [194]	Transverse myelitis	M/41	–	Bilateral paresthesia in upper and lower limbs, along with urinary and fecal retention	Serological study and CSF analysis, imaging studies	IV methylprednisolone	Associated with COVID-19 infection
72	Qazi et al. [195]/2021	Transverse myelitis	F/35	Pakistan	Abrupt bilateral lower limb weakness, paresthesia, and urinary retention	Serological study and CSF analysis, imaging studies	IV methylprednisolone (1 g/day for 7 days)	Associated with COVID-19 infection
73	Chow et al. [196]/2020	Transverse myelitis	M/60	Australia	Bilateral lower limb weakness, urinary retention, and constipation	Serological study and CSF analysis, imaging studies	IV methylprednisolone (1 g/day for 3 days)	Associated with COVID-19 infection
74	Sarma et al. [197]/2020	Transverse myelitis	F/28	USA	Lower back pain, bilateral symmetric upper and lower extremity numbness, and urinary retention	Serological study and CSF analysis, imaging studies	Prednisolone and plasma exchange	Associated with COVID-19 infection
75	Ahmad et al. [198]/2021	Transverse myelitis	F/34	Iraq	Progressive intermittent leg pain, paresthesia, and weakness on both sides	Serological study and CSF analysis, imaging studies	IV methylprednisolone (500 mg 1 × 1 for 5 days)	Associated with COVID-19 infection
76	Nejad Biglari et al. [199]/2021	Transverse myelitis	F/11	Iran	Acute paresis in the lower limbs, urinary and fecal retention	Serological study and CSF analysis, imaging studies	IVIg (0.4 g per kg body weight every day for 5 days) + pulse of methylprednisolone 30 mg/ Kg for 3 days	Associated with COVID-19 infection

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
77	Palahuta et al. [200]/2021	Transverse myelitis	M/23	Ukraine	Acute-onset non-compressive myelitis with bilateral paresthesia	Serological study and CSF analysis, imaging studies	IV methylprednisolone (1 g/day for 5 days)	Associated with COVID-19 infection
78	Lingas [201]/2022	Transverse myelitis	M/70	USA	Numbness on both lower limbs	Serological study and CSF analysis, imaging studies	IV methylprednisolone (high dose), IV Ig, ceftriaxone, ampicillin, and acyclovir	Associated with COVID-19 infection
79	Prete [202]/2022	Transverse myelitis	F/43	USA	Progressive numbness and tingling in lower limbs and complete quadriplegia	Serological study and CSF analysis, imaging studies	Long-term steroid regimen and plasmapheresis	Associated with COVID-19 infection
80	Shahali [203]/2021	Transverse myelitis	M/63	Iran	Weakness and immobility in lower extremities, constipation, and urinary retention	Serological study and CSF analysis, imaging studies	IV methylprednisolone (1 g/day for 3 days)	Associated with COVID-19 infection
81	Hsiao et al. [204]/2021	Transverse myelitis	M/41	Taiwan	Progressive paresis below T4, lower-limb weakness	Serological study and CSF analysis, imaging studies	IV methylprednisolone (1000 mg/day for 5 days)	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
82	Tan et al. [205]/2021	Transverse myelitis	F/25	Malaysia	Bilateral lower-limb weakness and impaired walking	Serological study and CSF analysis, imaging studies	IV methylprednisolone (1000 mg/day for 5 days)	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
83	Notghi et al. [206]/2021	Transverse myelitis	M/58	UK	Progressive numbness in lower limbs, allodynia up to chest level, genital dysaesthesia, and an episode of urinary incontinence	Serological study and CSF analysis, imaging studies	IV methylprednisolone (1 g/day for 5 days)	Associated with COVID-19 vaccination (Oxford/Astrazeneca)

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
84	Pagenkopf et al. [58]/2021	Transverse myelitis	M/45	Germany	Acute flaccid tetraparesis (especially in the lower limbs) and urinary retention	Serological study and CSF analysis, imaging studies	IV methylprednisolone (1 g/day for 5 days)	Associated with COVID-19 vaccination (Oxford/AstraZeneca)
85	Eom et al. [207]/2022	Transverse myelitis	M/81	Republic of Korea	Bilateral hand weakness and numbness	Serological study and CSF analysis, imaging studies	IV methylprednisolone (1 g/day for 5 days)	Associated with COVID-19 vaccination (Pfizer-BioNTech)
86	Eom et al. [207]/2022	Transverse myelitis	F/23	Republic of Korea	Bilateral paresthesia and weakness in the lower limbs	Serological study and CSF analysis, imaging studies	IV methylprednisolone (1 g/day for 5 days)	Associated with COVID-19 vaccination (Pfizer-BioNTech)
87	Miyaue et al. [208]/2022	Transverse myelitis	M/75	Japan	Total sensory loss below the umbilicus and complete paralysis in both lower limbs	Serological study and CSF analysis, imaging studies	IV methylprednisolone (1 g/day for 3 days), then oral prednisolone (initial dose of 1 mg/kg/day)	Associated with COVID-19 vaccination (Pfizer-BioNTech)
88	Maroufi et al. [209]/2022	Transverse myelitis	F/31	Iran	Progressive lower limbs paraparesis and paresthesia, urinary retention, and fecal incontinence	Serological study and CSF analysis, imaging studies	IV methylprednisolone (1 g/day for 7 days); Then, oral prednisolone 50 mg daily	Associated with COVID-19 vaccination (Oxford/AstraZeneca)
89	Tahir et al. [210]/2021	Transverse myelitis	F/44	USA	Numbness and weakness in the lower extremities, urinary retention, and back pain	Serological study and CSF analysis, imaging studies	IV methylprednisolone and plasma exchange	Associated with COVID-19 vaccination (Johnson and Johnson COVID-19 vaccine)
90	Hirose et al. [211]/2021	Transverse myelitis	M/70	Japan	Progressive sensorimotor dysfunction of both lower limbs	Serological study and CSF analysis, imaging studies	IV methylprednisolone (1000 mg/day for 5 days); then oral prednisolone (30 mg/day with gradual tapering)	Associated with COVID-19 vaccination (Moderna)

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
91	Rajae et al. [212]/2021	Cerebrovascular events (ischemic stroke)	M/68	Morocco	Left hemiparesis with dysarthria and left facial paralysis	Serological study and imaging studies (brain CT scan and MRI)	Thrombolysis	Associated with COVID-19 infection
92	Avvantaggiato et al. [213]/2021	Cerebrovascular events (ischemic stroke)	F/29	Italy	Left hemiplegia, left-sided central facial palsy, dysarthria, facial drop, and complete paralysis of the ipsilateral upper and lower limbs	Serological study and imaging studies (brain CT scan and MRI)	–	Associated with COVID-19 infection
93	Bigliardi et al. [214]/2020	Cerebrovascular events (ischemic stroke)	M/62	Italy	Left hemiplegia, left hemianopsia, and forced right deviation of gaze	Serological study and imaging studies (brain CT scan and chest CT angiography)	anticoagulant (LMWH)	Associated with COVID-19 infection
94	Zhai et al. [215]/2020	Cerebrovascular events (ischemic stroke)	M/79	China	Right limb weakness and non-fluent speech	Serological study and imaging studies (brain CT scan)	Clopidogrel (75 mg) and atorvastatin (20 mg)	Associated with COVID-19 infection
95	Farooque et al. [216]/2020	Cerebrovascular events (ischemic stroke)	M/70	Pakistan	Right-sided weakness and sensory loss in both upper and lower limbs	Serological study and imaging studies (brain CT scan and MRI)	Aspirin. (150 mg twice a day), LMWH (0.6 ml twice a day), and IV dexamethasone (1 cc twice a day)	Associated with COVID-19 infection
96	Owolabi et al. [217]/2021	Cerebrovascular events (hemorrhagic stroke)	M/59	Saudi Arabia	Right-sided incoordination, weakness, facial deviation, and altered level of consciousness	Serological study and imaging studies (brain CT scan)	Hydroxychloroquine, dexamethasone, remdesivir, and antibiotics	Associated with COVID-19 infection
97	Owolabi et al. [217]/2021	Cerebrovascular events (hemorrhagic stroke)	M/51	Saudi Arabia	Left-sided limb and facial weakness	Serological study and imaging studies (brain CT scan)	Hydroxychloroquine, dexamethasone, and antibiotics	Associated with COVID-19 infection
98	Fraiman et al. [218]/2020	Cerebrovascular events (hemorrhagic stroke)	F/38	Brazil	Acute alteration in the level of consciousness	Serological study and imaging studies (brain CT scan and MRI)	–	Associated with COVID-19 infection



Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
99	Flores et al. [219]/2020	Cerebrovascular events (hemorrhagic stroke)	M/40	USA	Pinpoint, minimally reactive pupils, withdrawal to painful stimuli in the right side of the body, left hemiparesis	Serological study and imaging studies (brain CT scan and MRI)	–	Associated with COVID-19 infection
100	Dakay et al. [220]/2021	Cerebrovascular events (cerebral venous sinus thrombosis)	M/17	USA	Left-sided headaches and occasional emesis	Serological study and imaging studies (MRI brain with MR venography)	Anticoagulation	Associated with COVID-19 infection
101	Dakay et al. [220]/2021	Cerebrovascular events (cerebral venous sinus thrombosis)	F/72	USA	Dyspnea and generalized weakness	Serological study and imaging studies (CT angiogram)	–	Associated with COVID-19 infection
102	Dakay et al. [220]/2021	Cerebrovascular events (cerebral venous sinus thrombosis)	M/26	USA	Acute left-sided hemiparesis followed by severe headache, nausea, and dizziness	Serological study and imaging studies (MRI brain with MR venography, brain CT scan, cerebral angiography, and CT angiogram)	–	Associated with COVID-19 infection
103	Anipindi et al. [221]/2021	Cerebrovascular events (cerebral venous sinus thrombosis)	M/66	USA	Severe headaches, palpitations, dizziness, and diaphoresis	Serological study and imaging studies (MRI and CT brain along with CT venogram)	Rivaroxaban 20 mg (6 months)	Associated with COVID-19 infection
104	Tu et al. [222]/2020	Cerebrovascular events (cerebral venous sinus thrombosis)	M/ mid-thirties	Singapore	Generalized non-remitting headache	Serological study and imaging studies (MRI and CT brain along with CT venogram and MR venogram)	Dabigatran	Associated with COVID-19 infection

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
105	Tu et al. [222]/2020	Cerebrovascular events (cerebral venous sinus thrombosis)	M/the late thirties	Singapore	First-onset seizure (generalized tonic-clonic convulsion)	Serological study and imaging studies (CT brain along with CT venogram)	IV heparin, IV levetiracetam, and cobalamin replacement	Associated with COVID-19 infection
106	Blauenfeldt et al. [78]/2021	Cerebrovascular events (ischemic stroke)	F/60	Denmark	Strong, persistent abdominal pain, headache	Serological study and imaging studies (CT brain)	Hemicraniectomy + postoperative dalteparin 5000 IU daily	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
107	Elaidouni et al. [223]/2022	Cerebrovascular events (ischemic stroke)	M/36	Morocco	Numbness in left hemibody, headaches (24 h after the vaccine injection),	Serological study and imaging studies (CT brain, MRI brain, MRI angiography of supra-aortic trunks)	Aspirin and Enoxaparin (100 UI/kg/12 h)	Associated with COVID-19 vaccination (Sinopharm)
108	Kenda et al. [224]/2021	Cerebrovascular events (ischemic stroke)	F/51	Slovenia	Acute-onset global aphasia, right-sided hemiplegia, and hemianopsia	Serological study and imaging studies (CT/MRI brain and CT angiography)	Mechanical thrombectomy + high-dose IV Ig (1 g/kg for 2 consecutive days)	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
109	Al-Mayhani et al. [225]/2021	Cerebrovascular events (ischemic stroke)	F/35	UK	Right temporal and periorbital headache	Serological study and imaging studies (CT brain and CT angiography)	Urgent decompressive hemicraniectomy, IV Ig, plasmapheresis, and fondaparinux	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
110	Al-Mayhani et al. [225]/2021	Cerebrovascular events (ischemic stroke)	F/37	UK	Diffused headache, left visual field loss, confusion, and left arm weakness	Serological study and imaging studies (diffusion-weighted MRI and CT angiography)	IV Ig, IV methylprednisolone, plasmapheresis, and fondaparinux	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
111	de Mello Silva et al. [226]/2021	Cerebrovascular events (hemorrhagic stroke)	F/57	Brazil	Acute-onset sweating and paleness, followed by left-sided hemiparesis, vomiting, and somnolence	Serological study and imaging studies (CT brain)	Hematoma drainage, external ventricular drain, and decompressive craniectomy	Associated with COVID-19 vaccination (Oxford/Astrazeneca)

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
112	Takeyama et al. [227]/2022	Cerebrovascular events (hemorrhagic stroke)	F/48	Japan	Gradually progressing left-sided hemiparesis	Serological study and imaging studies (CT/MRI brain and CT angiography)	Right frontotemporal craniotomy	Associated with COVID-19 vaccination (Pfizer-BioNTech)
113	Dias et al. [228]/2021	Cerebrovascular events (cerebral venous sinus thrombosis)	F/47	Portugal	The sudden left-sided motor deficit, papilledema, left visual extinction, right gaze deviation, and left hemiparesis	Serological study and imaging studies (MRI brain, MRI venography)	Acetazolamide and enoxaparin 60 mg twice a day (later changed to warfarin)	Associated with COVID-19 vaccination (Pfizer-BioNTech)
114	Dias et al. [228]/2021	Cerebrovascular events (cerebral venous sinus thrombosis)	F/67	Portugal	Sudden right-sided lower limb clonic movements, motor deficit, loss of consciousness, and headache	Serological study and imaging studies (MRI brain) and Electroencephalography	Levetiracetam (500 mg twice a day) and enoxaparin (80 mg twice a day); then switched to dabigatran (150 mg twice a day)	Associated with COVID-19 vaccination (Pfizer-BioNTech)
115	Zakaria et al. [229]/2021	Cerebrovascular events (cerebral venous sinus thrombosis)	M/49	Malaysia	A new-onset headache and giddiness	Serological study and imaging studies (CT brain and CT cerebral venogram)	Subcutaneous Clexane (1 mg/kg twice a day) and clopidogrel (75 mg)	Associated with COVID-19 vaccination (Pfizer-BioNTech)
116	D'Agostino et al. [230]/2021	Cerebrovascular events (cerebral venous sinus thrombosis)	F/54	Italy	Left-sided signs	Serological study and imaging studies (CT/MRI brain and CT/MRI angiography)	–	Associated with COVID-19 vaccination (Oxford/AstraZeneca)
117	Atta et al. [231]/2021	Cerebrovascular events (cerebral venous sinus thrombosis)	F/48	UK	Right-sided headache,	Serological study and imaging studies (CT cerebral venogram)	Fondaparinux (7.5 mg), IVIg (1 g/kg) and dexamethasone (20 mg/day)	Associated with COVID-19 vaccination (Oxford/AstraZeneca)

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
118	Delorme et al. [232]/2020	Encephalopathy	M/72	France	Acute psychomotor agitation, cognitive and behavioral frontal lobe syndrome, upper limbs myoclonus, and cerebellar ataxia	CSF analysis, electroencephalogram (EEG), brain MRI, and brain FDG-PET/CT imaging	IVIg (2 g/kg)	Associated with COVID-19 infection
119	Delorme et al. [232]/2020	Encephalopathy	F/66	France	Acute cognitive impairment, psychomotor slowing, cognitive and behavioral frontal lobe syndrome, and severe apraxia	CSF analysis, EEG, brain MRI, and brain FDG-PET/CT imaging	IVIg; then, due to persisting severe cognitive impairment, IV pulse corticosteroids (2 mg/kg/day 3 days then 1 g/day 3 days) started	Associated with COVID-19 infection
120	Delorme et al. [232]/2020	Encephalopathy	F/60	France	Acute anxiety, depressed mood, akathisia, gait imbalance, psychomotor agitation, dysexecutive syndrome, and cerebellar ataxia	CSF analysis, EEG, brain MRI, and brain FDG-PET/CT imaging	Pulse corticosteroids (2 mg/kg/day 3 days)	Associated with COVID-19 infection
122	Delorme et al. [232]/2020	Encephalopathy	M/69	France	Generalized convulsive status epilepticus, fever, fatigue, anosmia, and ageusia	CSF analysis, EEG, brain MRI, and brain FDG-PET/CT imaging	Pulse corticosteroids (1 g/day 5 days)	Associated with COVID-19 infection
123	Lazraq et al. [233]/2021	Encephalopathy	M/79	Morocco	Mental confusion, sudden-onset dysarthria	The serological study, CSF analysis, EEG, brain CT, MRI, and MR angiography	Sodium valproate	Associated with COVID-19 infection
124	Goodloe et al. [234]/2021	Encephalopathy	M/52	USA	Altered mental status, fever, and severe agitation	The serological study, CSF analysis, EEG, brain CT, and MRI	Vancomycin, ceftriaxone, azithromycin, acyclovir, and clevudipine	Associated with COVID-19 infection

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
125	Teimouri-Jervekani et al. [235]/2021	Encephalopathy	M/53	Iran	Severe headache and bizarre behavior	The serological study, brain CT and MRI	Hydroxychloroquine (200 mg twice a day for 5 days)	Associated with COVID-19 infection
126	Al-Mashdali et al. [236]/2021	Encephalopathy	M/32	Qatar	Acute confusion, disturbed memory, and auditory hallucination	The serological study, CSF analysis, EEG, and brain MRI	Methylprednisolone	Associated with COVID-19 vaccination (Moderna)
127	Liu et al. [237]/2021	Encephalopathy	F/86	USA	Acute confusion with visual hallucinations and left frontal headache	The serological study, CSF analysis, EEG, brain CT, and MRI	Lorazepam, fosphenytoin, and discharged with levetiracetam	Associated with COVID-19 vaccination (Moderna)
128	Liu et al. [237]/2021	Encephalopathy	M/73	USA	Cognitive deficits, hallucinations, and periods of unresponsiveness	The serological study, CSF analysis, EEG, brain CT, and MRI	Lorazepam and levetiracetam	Associated with COVID-19 vaccination (Moderna)
129	Baldelli et al. [108]/2021	Encephalopathy	M/77	Italy	Confusion, agitation, and delirium	The serological study, CSF analysis, EEG, brain CT, and MRI	Oral prednisone (50 mg per day)	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
130	Bensaidane et al. [238]/2022	Encephalopathy	M/56	Canada	Altered mental status	The serological study, CSF analysis, EEG, brain CT angiography, and MRI	High-dose IV methylprednisolone (1 g/day for 7 days)	Associated with COVID-19 vaccination (Oxford/Astrazeneca)
131	Monti et al. [239]/2020	New-onset seizures	M/50	Italy	Acute onset of psychiatric symptoms (confabulations and delirious ideas), focal motor seizures, and impaired awareness	The serological study, CSF analysis, EEG, brain MRI, and total-body CT and PET	Diazepam, valproic acid, lacosamide, methylprednisolone, IVIg, plasma-exchange	Associated with COVID-19 infection
132	Bhatta et al. [240]/2020	New-onset seizures	M/11	USA	Acute-onset seizure for 2 min	The serological study, EEG, and brain CT	Levetiracetam (500 mg twice a day)	Associated with COVID-19 infection

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
133	Park et al. [241]/2021	New-onset seizures	F/45	USA	Focal to bilateral tonic-clonic seizure, loss of consciousness, and urinary incontinence	The serological study, CSF analysis, EEG, brain MRI, and CT	Oxcarbazepine (600 mg twice a day); then lacosamide (200 mg twice a day)	Associated with COVID-19 infection
134	Dono et al. [242]/2021	New-onset seizure	M/81	Italy	Non-convulsive status epilepticus with coma	The serological study, CSF analysis, EEG, brain MRI, and CT	Lorazepam (4 mg two IV boluses), levetiracetam (2000 mg IV), methylprednisolone (1 g/daily IV for 5 days); then, oral prednisolone (60 mg/day for 10 days) and IVIg (160 g over 5 days)	Associated with COVID-19 infection
135	Cho et al. [243]/2022	New-onset seizures	M/84	Korea	Myoclonic seizures (Myoclonic status epilepticus)	The serological study, EEG, brain Diffusion-weighted MRI	Sedative medication: Midazolam Antiseizure medication: Lorazepam and Levetiracetam	Associated with COVID-19 infection
136	Cho et al. [243]/2022	New-onset seizures	M/45	Korea	Focal to bilateral tonic-clonic seizures (2 times)	Serological study and EEG	Sedative medication: Remifentanyl and Dexmedetomidine Antiseizure medication: Lorazepam and Levetiracetam	Associated with COVID-19 infection
137	Cho et al. [243]/2022	New-onset seizures	M/63	Korea	Focal impaired aware seizures (several times)	Serological study and EEG	Sedative medication: Dexmedetomidine Antiseizure medication: Phenobarbital, Levetiracetam, Topiramate, and Perampamil	Associated with COVID-19 infection



Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
138	Cho et al. [243]/2022	New-onset seizures	M/72	Korea	Myoclonic seizure, generalized tonic-clonic seizures (several times)	Serological study and EEG	Sedative medication: Remifentanyl and Dexmedetomidine Antiseizure medication: Levetiracetam and Topiramate	Associated with COVID-19 infection
139	Cho et al. [243]/2022	New-onset seizures	M/73	Korea	Myoclonic seizures (several times)	Serological study and EEG	Sedative medication: Remifentanyl and Propofol Antiseizure medication: Levetiracetam and Valproic acid	Associated with COVID-19 infection
140	Cho et al. [243]/2022	New-onset seizures	F/39	Korea	Generalized tonic-clonic seizures (3 times)	The serological study, EEG, brain CT	Sedative medication:—Antiseizure medication: Levetiracetam	Associated with COVID-19 infection
141	Aladdin et al. [119]/2021	New-onset seizures	F/42	Saudi Arabia	Generalized tonic-clonic seizure	The serological study, CSF analysis, EEG, and brain MRI	Lorazepam, phenytoin, levetiracetam, and lacosamide	Associated with COVID-19 vaccination (Oxford/AstraZeneca)
142	Bauman et al. [244]	New-onset seizures	M/56	USA	New-onset refractory status epilepticus	The serological study, CSF analysis, EEG, and brain MRI	Corticosteroids, plasmapheresis, IVIg, rituximab, midazolam, propofol, ketamine, levetiracetam, lacosamide, phenobarbital, clobazam, zonisamide, oxcarbazepine, and perampanel	Associated with COVID-19 vaccination (Pfizer-BioNTech)
143	Desai et al. [245]/2021	Varicella-zoster virus reactivation	F/62	India	Painful blisters and fluid-filled bubble-form rashes	Serological studies	Oral and topical Acyclovir	Associated with COVID-19 infection

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
144	Saleh et al. [246]/2021	Varicella-zoster virus reactivation	F/49	Egypt	Unilateral fluid-filled vesicles and painful erythematous areas over the hard palate	Serological studies	Oral acyclovir, topical antiseptics, chlorhexidine, and paracetamol	Associated with COVID-19 infection
145	Saati et al. [122]/2020	Varicella-zoster virus reactivation	M/57	Saudi Arabia	Fluid-filled bubble-form rashes and vesicles with surrounding erythematous areas over the right nipple	Serological studies	Famciclovir	Associated with COVID-19 infection
146	Van Dam et al. [129]/2021	Varicella-zoster virus reactivation	F/29	The Netherlands	Painful multiple vesicles on the left side of the ox coccyges	Clinically diagnosed	–	Associated with COVID-19 vaccination (Pfizer-BioNTech)
147	Van Dam et al. [247]/2021	Varicella-zoster virus reactivation	M/34	The Netherlands	Swollen, painful inguinal lymph nodes and a rash on the right lower limb	Serological studies and PCR tests over vesical fluid for VZV	Valacyclovir	Associated with COVID-19 vaccination (Pfizer-BioNTech)
148	Rodríguez-Jiménez et al. [248]/2021	Varicella-zoster virus reactivation	M/58	Spain	Asymptomatic herpes-form umbilicated vesicles and lymphadenopathy in the cervical area	PCR	–	Associated with COVID-19 vaccination (Pfizer-BioNTech)
149	Rodríguez-Jiménez et al. [248]/2021	Varicella-zoster virus reactivation	F/47	Spain	Herpes-form umbilicated vesicles and dysesthesia	PCR	–	Associated with COVID-19 vaccination (Pfizer-BioNTech)
150	Rodríguez-Jiménez et al. [248]/2021	Varicella-zoster virus reactivation	M/39	Spain	Painful herpes-form umbilicated vesicles	–	–	Associated with COVID-19 vaccination (Pfizer-BioNTech)
151	Rodríguez-Jiménez et al. [248]/2021	Varicella-zoster virus reactivation	F/56	Spain	Herpes-form umbilicated vesicles	PCR	–	Associated with COVID-19 vaccination (Pfizer-BioNTech)

Table 2 (continued)

Case number	Reference	Neurological disorder	Sex/Age (years)	Country	Clinical manifestation	Diagnosis	Treatment	Associated with SARS-CoV-2 infection vs post-COVID-19 vaccination
152	Rodríguez-Jiménez et al. [248]/2021	Varicella-zoster virus reactivation	F/41	Spain	Herpes-form umbilicated vesicles and dysesthesia	-	-	Associated with COVID-19 vaccination (Pfizer-BioNTech)
153	Santovito et al. (249)/2021	Varicella-zoster virus reactivation	M/27	USA	Popular rashes over the left upper limb	-	-	Associated with COVID-19 vaccination (Pfizer-BioNTech)

## Miscellaneous neurological adverse events

Apart from the aforementioned neurological side effects, some other AEs, including narcolepsy, small fiber neuropathy, neuroleptic malignant syndrome (NMS), and multiple sclerosis flare-ups, have been reported following COVID-19 vaccination, although their causal relationships are not confirmed [4, 136–139].

## Relative risks of neurological adverse events in SARS-CoV-2 infection vs. post-COVID-19 vaccination

Many studies have reported various neurological disorders associated with COVID-19 infection and vaccines [80, 140–143]. However, given the shortage of comprehensive, prospective studies, it is still far too difficult to establish cause-effect relations between these factors. Therefore, future studies should determine the real risk of these adverse events following COVID-19 vaccination. Until then, it does not seem reasonable to limit vaccine administration. Nonetheless, considering the existing data, in this section, we have summarized some studies reporting cases of neurological adverse events associated with SARS-CoV-2 infection or vaccination (Table 2).

## Conclusion

The present review can help healthcare workers and also the general population by emphasizing these points: any neurological symptom after COVID-19 vaccination can be potentially critical and needs to be cautiously evaluated; for any suspected adverse event following vaccination, we should initially exclude current or recent SARS-CoV-2 infection; and despite the current literature on serious complications imposed by COVID-19 vaccines, the benefits of vaccination outweigh the risks in ending the current pandemic since all of these complications can occur with the infection itself.

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**Data Availability** The data that support the findings of this study are available from the corresponding author upon reasonable request.

## Declarations

**Conflict of interest** Terence T. Sio reports that he provides strategic and scientific recommendations as a member of the Advisory Board and speaker for Novocure, Inc. and also as a member of the Advisory Board to Galera Therapeutics, which are not in any way associated with the content or disease site as presented in this manuscript. All other authors have no relevant financial interests to be declared.

## References

- Goss AL, Samudralwar RD, Das RR, Nath A (2021) ANA investigates: neurological complications of COVID-19 vaccines. *Ann Neurol* 89(5):856–857
- Malhotra HS, Gupta P, Prabhu V, Kumar Garg R, Dandu H, Agarwal V. COVID-19 vaccination-associated myelitis. *QJM: An International Journal of Medicine*. 2021 Aug;114(8):591-3.
- von Csefalvay C. A case-control study of autoimmune AEFIs following COVID-19 vaccination reported to VAERS. medRxiv. 2021 Jan 1.
- Al Battah A, Hammamy R. Multiple sclerosis flare secondary to COVID-19 vaccine, a case report. *Authorea Preprints*. 2021 Jul 25.
- Finsterer J, Scorza FA, Fiorini AC (2021) SARS-CoV-2 infection/vaccination associated new or exacerbating immune-mediated disease. *J Med Res Health Sci* 4(6):1302–1304
- Watad A, De Marco G, Mahajna H, Druyan A, Eltity M, Hijazi N et al (2021) Immune-mediated disease flares or new-onset disease in 27 subjects following mrna/dna sars-cov-2 vaccination. *Vaccines (Basel)* 9(5):435
- Althaus K, Moller P, Uzun G, Singh A, Beck A, Bettag M et al (2021) Antibody-mediated procoagulant platelets in SARS-CoV-2-vaccination associated immune thrombotic thrombocytopenia. *Haematologica* 106(8):2170–2179
- Hause AM, Gee J, Baggs J, Abara WE, Marquez P, Thompson D et al (2021) COVID-19 vaccine safety in adolescents aged 12–17 years-United States, december 14, 2020-july 16, 2021. *MMWR Morb Mortal Wkly Rep* 70(31):1053–1058
- Ogidi OI, Berefagha WL, Okara E (2021) Covid-19 vaccination: the pros and cons. *World J Biol Pharm Health Sci* 7(1):015–022
- García-Grimshaw M, Hernández-Vanegas LE, Núñez I, Hernández-Valdivia N, Carrillo-García DA, Michel-Chávez A, Galnares-Olalde JA, Carbajal-Sandoval G, del Mar Saniger-Alba M, Carrillo-Mezo RA, Fragoso-Saavedra S. Neurologic adverse events among 704,003 first-dose recipients of the BNT162b2 mRNA COVID-19 vaccine in Mexico: a nationwide descriptive study. *Clinical Immunology*. 2021 Aug 1;229:108786.
- Zavala-Jonguitud LF, Perez-Garcia CC (2021) Delirium triggered by COVID-19 vaccine in an elderly patient. *Geriatr Gerontol Int* 21(6):540
- Iftikhar H, Noor SMU, Masood M, Bashir K (2021) Bell's Palsy after 24 hours of mrna-1273 sars-cov-2 vaccine. *Cureus* 13(6):e15935
- McCormick DP, Spruance SL (2000) Herpes simplex virus as a cause of Bell's palsy. *Rev Med Virol* 10(5):285
- Tamaki A, Cabrera CI, Li S, Rabbani C, Thuener JE, Rezaee RP et al (2021) Incidence of Bell Palsy in patients with covid-19. *JAMA Otolaryngol Head Neck Surg* 147(8):767–768
- Oke IO, Oladunjoye OO, Oladunjoye AO, Paudel A, Zimmerman R (2021) Bell's Palsy as a late neurological manifestation of covid-19 infection. *Cureus*. <https://doi.org/10.7759/cureus.13881>
- Bastola A, Sah R, Nepal G, Gajurel BP, Rajbhandari SK, Chalise BS et al (2021) Bell's palsy as a possible neurological complication of COVID-19: a case report. *Clinical Case Reports* 9(2):747–750
- Alp H, Tan H, Orbak Z (2009) Bell's palsy as a possible complication of hepatitis B vaccination in a child. *J Health Popul Nutr* 27(5):707
- Chou CH, Liou WP, Hu KI, Loh CH, Chou CC, Chen YH (2007) Bell's palsy associated with influenza vaccination: two case reports. *Vaccine* 25(15):2839–2841
- Tseng HF, Sy LS, Ackerson BK, Hechter RC, Tartof SY, Haag M et al (2017) Safety of Quadrivalent Meningococcal Conjugate Vaccine in 11- to 21-Year-Olds. *Pediatrics*. <https://doi.org/10.1542/peds.2016-2084>
- Colella G, Orlandi M, Cirillo N (2021) Bell's palsy following COVID-19 vaccination. *J Neurol* 268(10):3589–3591
- Martin-Villares C, Vazquez-Feito A, Gonzalez-Gimeno MJ, de la Nogal-Fernandez B. Bell's palsy following a single dose of mRNA SARS-CoV-2 vaccine: a case report. *Journal of Neurology*. 2022 Jan;269(1):47-8.
- Ledford H (2020) US authorization of first COVID vaccine marks new phase in safety monitoring. *Nature* 588(7838):377–378
- Pothiwala S (2021) Bell's Palsy after second dose of moderna COVID-19 Vaccine: coincidence or causation? *Acta medica Lituanica*. 28(2):7
- Kamath A, Maity N, Nayak MA (2020) Facial paralysis following influenza vaccination: a disproportionality analysis using the vaccine adverse event reporting system database. *Clin Drug Investig* 40(9):883–889
- Principi N, Esposito S. Do vaccines have a role as a cause of autoimmune neurological syndromes?. *Frontiers in Public Health*. 2020 Jul 28;8:361.
- Soeiro T, Salvo F, Pariente A, Grandvilllemin A, Jonville-Béra A-P, Micallef J (2021) Type I interferons as the potential mechanism linking mRNA COVID-19 vaccines to Bell's palsy. *Therapie*. <https://doi.org/10.1016/j.therap.2021.03.005>
- Burrows A, Bartholomew T, Rudd J, Walker D (2021) Sequential contralateral facial nerve palsies following COVID-19 vaccination first and second doses. *BMJ Case Reports CP* 14(7):e243829
- Repajic M, Lai XL, Xu P, Liu A (2021) Bell's Palsy after second dose of Pfizer COVID-19 vaccination in a patient with history of recurrent Bell's palsy. *Brain Behav Immun Health* 13:100217
- Wan EYF, Chui CSL, Lai FTT, Chan EWY, Li X, Yan VKC et al (2021) Bell's palsy following vaccination with mRNA (BNT162b2) and inactivated (CoronaVac) SARS-CoV-2 vaccines: a case series and nested case-control study. *Lancet Infect Dis*. [https://doi.org/10.1016/S1473-3099\(21\)00451-5](https://doi.org/10.1016/S1473-3099(21)00451-5)
- Li X, Ostropelets A, Makadia R, Shoaibi A, Rao G, Sena AG, Martinez-Hernandez E, Delmestri A, Verhamme K, Rijnbeek PR, Duarte-Salles T. Characterising the background incidence rates of adverse events of special interest for covid-19 vaccines in eight countries: multinational network cohort study. *bmj*. 2021 Jun 14;373.
- Cirillo N, Doan R (2021) Bell's palsy and SARS-CoV-2 vaccines-an unfolding story. *Lancet Infect Dis* 21(9):1210–1211
- Baugh RF, Basura GJ, Ishii LE, Schwartz SR, Drumheller CM, Burkholder R et al (2013) Clinical practice guideline: Bell's palsy. *Otolaryngology-Head Neck Surg*. <https://doi.org/10.1177/0194599813505967>
- Haber P, Sejvar J, Mikaeloff Y, DeStefano F (2009) Vaccines and Guillain-Barre syndrome. *Drug Saf* 32(4):309–323

34. Loza AMM, Holroyd KB, Johnson SA, Pilgrim DM, Amato AA (2021) Guillain-Barré syndrome in the placebo and active arms of a COVID-19 vaccine clinical trial: temporal associations do not imply causality. *Neurology* 96(22):1052–1054
35. Babazadeh A, Mohseni Afshar Z, Javanian M, Mohammadnia-Afrouzi M, Karkhah A, Masrou-Roudsari J et al (2019) Influenza vaccination and guillain-barre syndrome: reality or fear. *J Transl Int Med* 7(4):137–142
36. Juurlink DN, Stukel TA, Kwong J, Kopp A, McGeer A, Upshur RE et al (2006) Guillain-Barre syndrome after influenza vaccination in adults: a population-based study. *Arch Intern Med* 166(20):2217–2221
37. Souayah N, Michas-Martin PA, Nasar A, Krivitskaya N, Yacoub HA, Khan H et al (2011) Guillain-Barre syndrome after Gardasil vaccination: data from vaccine adverse event reporting system 2006–2009. *Vaccine* 29(5):886–889
38. Tuttle J, Chen RT, Rantala H, Cherry JD, Rhodes PH, Hadler S (1997) The risk of Guillain-Barre syndrome after tetanus-toxoid-containing vaccines in adults and children in the United States. *Am J Public Health* 87(12):2045–2048
39. Centers for Disease Control and Prevention (CDC. Update: Guillain-Barré syndrome among recipients of Menactra meningococcal conjugate vaccine--United States, June 2005-September 2006. *MMWR. Morbidity and mortality weekly report*. 2006 Oct 20;55(41):1120-4.
40. Waheed S, Bayas A, Hindi F, Rizvi Z, Espinosa PS (2021) Neurological complications of COVID-19: Guillain-Barre syndrome following Pfizer COVID-19 vaccine. *Cureus*. <https://doi.org/10.7759/cureus.13426>
41. James J, Jose J, Gafoor VA, Smita B, Balaram N (2021) Guillain-Barre syndrome following ChAdOx1 nCoV-19 COVID-19 vaccination: a case series. *Neurol Clin Neurosci* 9(5):402–405
42. Patel SU, Khurram R, Lakhani A, Quirk B (2021) Guillain-Barre syndrome following the first dose of the chimpanzee adenovirus-vectored COVID-19 vaccine, ChAdOx1. *BMJ Case Rep* 14(4):e242956
43. Prasad A, Hurlburt G, Podury S, Tandon M, Kingree S, Sriwastava S (2021) A Novel case of bifacial diplegia variant of guillain-barre syndrome following janssen covid-19 vaccination. *Neurol Int* 13(3):404–409
44. Leonhard SE, Mandarakas MR, Gondim FAA, Bateman K, Ferreira MLB, Cornblath DR et al (2019) Diagnosis and management of Guillain-Barre syndrome in ten steps. *Nat Rev Neurol* 15(11):671–683
45. Leonhard SE, Mandarakas MR, Gondim FA, Bateman K, Ferreira ML, Cornblath DR et al (2019) Diagnosis and management of Guillain-Barré syndrome in ten steps. *Nat Rev Neurol* 15(11):671–683
46. West TW (2013) Transverse myelitis—a review of the presentation, diagnosis, and initial management. *Discov Med* 16(88):167–177
47. Munz M, Wessendorf S, Koretsis G, Tewald F, Baegi R, Kramer S et al (2020) Acute transverse myelitis after COVID-19 pneumonia. *J Neurol* 267(8):2196–2197
48. Zachariadis A, Tulbu A, Strambo D, Dumoulin A, Di Virgilio G (2020) Transverse myelitis related to COVID-19 infection. *J Neurol* 267(12):3459–3461
49. Agmon-Levin N, Kivity S, Szyper-Kravitz M, Shoenfeld Y (2009) Transverse myelitis and vaccines: a multi-analysis. *Lupus* 18(13):1198–1204
50. Akkad W, Salem B, Freeman JW, Huntington MK (2010) Longitudinally extensive transverse myelitis following vaccination with nasal attenuated novel influenza A(H1N1) vaccine. *Arch Neurol* 67(8):1018–1020
51. Kelly H (2006) Evidence for a causal association between oral polio vaccine and transverse myelitis: a case history and review of the Literature. *J Paediatr Child Health* 42(4):155–159
52. Iniguez C, Mauri JA, Larrode P, Lopez del Val J, Jerico I, Morales F (2000) Acute transverse myelitis secondary to hepatitis B vaccination. *Rev Neurol* 31(5):430–432
53. Joyce KA, Rees JE (1995) Transverse myelitis after measles, mumps, and rubella vaccine. *BMJ* 311(7002):422
54. Read SJ, Schapel GJ, Pender MP (1992) Acute transverse myelitis after tetanus toxoid vaccination. *Lancet* 339(8801):1111–1112
55. Voysey M, Clemens SAC, Madhi SA, Weckx LY, Folegatti PM, Aley PK et al (2021) Safety and efficacy of the ChAdOx1 nCoV-19 vaccine (AZD1222) against SARS-CoV-2: an interim analysis of four randomised controlled trials in Brazil, South Africa, and the UK. *Lancet* 397(10269):99–111
56. Narasimhalu K, Lee WC, Salkade PR, De Silva DA (2021) Trigeminal and cervical radiculitis after tozinameran vaccination against COVID-19. *BMJ Case Rep* 14(6):e242344
57. Evans SJW, Day SJ. Medicines and Healthcare Products Regulatory Agency (MHRA) (Formerly MCA). In: Armitage P, Colton T, editors. *Encyclopedia of Biostatistics*, 2005
58. Pagenkopf C, Sudmeyer M (2021) A case of longitudinally extensive transverse myelitis following vaccination against Covid-19. *J Neuroimmunol* 358:577606
59. Song E, Zhang C, Israelow B, Lu-Culligan A, Prado AV, Skriabine S et al (2021) Neuroinvasion of SARS-CoV-2 in human and mouse brain. *J Exp Med* 218(3):e20202135
60. Vera-Lastra O, Medina G, Cruz-Dominguez Mdel P, Jara LJ, Shoenfeld Y (2013) Autoimmune/inflammatory syndrome induced by adjuvants (Shoenfeld's syndrome): clinical and immunological spectrum. *Expert Rev Clin Immunol* 9(4):361–373
61. Roman GC, Gracia F, Torres A, Palacios A, Gracia K, Harris D (2021) Acute Transverse Myelitis (ATM): clinical review of 43 patients with COVID-19-associated atm and 3 post-vaccination atm serious adverse events with the chadox1 ncv-19 vaccine (AZD1222). *Front Immunol* 12:653786
62. Calvo AC, Martínez MAM, Alentorn-Palau A, Escuer JB, Pinel LR, Martínez-Yélamos S (2013) Idiopathic acute transverse myelitis: outcome and conversion to multiple sclerosis in a large series. *BMC Neurol* 13(1):1–8
63. Beh SC, Greenberg BM, Frohman T, Frohman EM (2013) Transverse myelitis. *Neurol Clin* 31(1):79–138
64. Scott T, Frohman E, De Seze J, Gronseth G, Weinshenker B (2011) Evidence-based guideline: clinical evaluation and treatment of transverse myelitis: report of the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology. *Neurology*. <https://doi.org/10.1212/WNL.0b013e31823dc535>
65. Chow CCN, Magnussen J, Ip J, Su Y (2020) Acute transverse myelitis in COVID-19 infection. *BMJ Case Reports CP* 13(8):e236720
66. Shahjouei S, Naderi S, Li J, Khan A, Chaudhary D, Farahmand G et al (2020) Risk of stroke in hospitalized SARS-CoV-2 infected patients: a multinational study. *EBioMedicine* 59:102939
67. Qureshi AI, Baskett WI, Huang W, Shyu D, Myers D, Raju M et al (2021) Acute ischemic stroke and COVID-19: an analysis of 27 676 patients. *Stroke* 52(3):905–912
68. Gunduz ZB (2021) Venous sinus thrombosis during COVID-19 infection in pregnancy: a case report. *Sao Paulo Med J* 139(2):190–195
69. Markus HS (2021) Ischaemic stroke can follow COVID-19 vaccination but is much more common with COVID-19 infection itself. *BMJ Publishing Group Ltd*. <https://doi.org/10.1136/jnnp-2021-327057>



70. Finsterer J, Korn M (2021) Aphasia seven days after second dose of an mRNA-based SARS-CoV-2 vaccine. *Brain Hemorrhages*. <https://doi.org/10.1016/j.hest.2021.06.001>
71. Mohseni Afshar Z, Babazadeh A, Janbakhsh A, Afsharian M, Saleki K, Barary M et al (2021) Vaccine-induced immune thrombotic thrombocytopenia after vaccination against Covid-19: A clinical dilemma for clinicians and patients. *Rev Med Virol*. <https://doi.org/10.1002/rmv.2273>
72. Mittelmeier H (1959) Generalized anaphylactic toxic blood vessel wall injury with sinus thrombosis after active diphtheria vaccination with a study on the etiology and pathogenesis of organic blood vessel diseases. *Monatsschr Kinderheilkd* 107(6):288–293
73. Nieminen U, Peltola H, Syrjala MT, Makiperna A, Kekomaki R (1993) Acute thrombocytopenic purpura following measles, mumps and rubella vaccination. A report on 23 patients. *Acta Paediatr* 82(3):267–270
74. Vickers ER, McClure DL, Naleway AL, Jacobsen SJ, Klein NP, Glanz JM et al (2017) Risk of venous thromboembolism following influenza vaccination in adults aged 50 years and older in the vaccine safety datalink. *Vaccine* 35(43):5872–5877
75. Oldenburg J, Klamroth R, Langer F, Albisetti M, von Auer C, Ay C et al (2021) Diagnosis and management of vaccine-related thrombosis following AstraZeneca COVID-19 vaccination: guidance statement from the GTH. *Hamostaseologie*. <https://doi.org/10.1055/a-1469-7481>
76. See I, Su JR, Lale A, Woo EJ, Guh AY, Shimabukuro TT et al (2021) 2021 US case reports of cerebral venous sinus Thrombosis with Thrombocytopenia after Ad26.COV2.S vaccination, March 2 to April 21. *JAMA* 325(24):2448–2456
77. Muir KL, Kallam A, Koepsell SA, Gundabolu K (2021) Thrombotic Thrombocytopenia after Ad26.COV2S Vaccination. *N Engl J Med*. <https://doi.org/10.1056/NEJMc2105869>
78. Blauenfeldt RA, Kristensen SR, Ernstsens SL, Kristensen CCH, Simonsen CZ, Hvas AM (2021) Thrombocytopenia with acute ischemic stroke and bleeding in a patient newly vaccinated with an adenoviral vector-based COVID-19 vaccine. *J Thromb Haemost* 19(7):1771–1775
79. Al-Mayhani T, Saber S, Stubbs MJ, Losseff NA, Perry RJ, Simister RJ et al (2021) Ischaemic stroke as a presenting feature of ChAdOx1 nCoV-19 vaccine-induced immune thrombotic thrombocytopenia. *J Neurol Neurosurg Psychiatry*. <https://doi.org/10.1136/jnnp-2021-326984>
80. Mehta PR, Apap Mangion S, Bengier M, Stanton BR, Czuprynska J, Arya R et al (2021) Cerebral venous sinus thrombosis and thrombocytopenia after COVID-19 vaccination - a report of two UK cases. *Brain Behav Immun* 95:514–517
81. Wolf ME, Luz B, Niehaus L, Bhogal P, Bätzner H, Henkes H (2021) Thrombocytopenia and intracranial venous sinus thrombosis after “COVID-19 vaccine AstraZeneca” exposure. *J Clin Med* 10(8):1599
82. Schultz NH, Sorvoll IH, Michelsen AE, Munthe LA, Lund-Johansen F, Ahlen MT et al (2021) Thrombosis and Thrombocytopenia after ChAdOx1 nCoV-19 vaccination. *N Engl J Med* 384(22):2124–2130
83. Bjørnstad-Tuveng TH, Rudjord A, Anker P. Fatal cerebral haemorrhage after COVID-19 vaccine. *Tidsskr Nor Laegeforen*. 2021 Apr 29;141.
84. Mahmoodi BK, Brouwer J-LP, Veeger NJ, van der Meer J (2008) Hereditary deficiency of protein C or protein S confers increased risk of arterial thromboembolic events at a young age: results from a large family cohort study. *Circulation* 118(16):1659–1667
85. Simpson EL, Lawrenson RA, Nightingale AL, Farmer RD (2001) Venous thromboembolism in pregnancy and the puerperium: incidence and additional risk factors from a London perinatal database. *BJOG* 108(1):56–60
86. Lin J, Wakefield TW, Henke PK (2006) Risk factors associated with venous thromboembolic events in patients with malignancy. *Blood Coagul Fibrinolysis* 17(4):265–270
87. Ageno W, Squizzato A, Garcia D, Imberti D. Epidemiology and risk factors of venous thromboembolism. *Semin Thromb Hemost*. 2006;32(7):651-8.
88. Dutta A, Ghosh R, Bhattacharya D, Bhat S, Ray A, Pandit A et al (2021) Anti-PF4 antibody negative cerebral venous sinus thrombosis without thrombocytopenia following immunization with COVID-19 vaccine in an elderly non-comorbid Indian male, managed with conventional heparin-warfarin based anticoagulation. *Diabetes Metab Syndr* 15(4):102184
89. Shakibajahromi B, Haghghi AB, Salehi A, Vardanjani HM, Ghaedian M, Safari A et al (2020) Clinical and radiological characteristics and predictors of outcome of cerebral venous sinus thrombosis, a hospital-based study. *Acta Neurol Belg* 120(4):845–852
90. McCrae KR (2021) Thrombotic thrombocytopenia due to SARS-CoV-2 vaccination. *Cleveland Clin J Med*. <https://doi.org/10.3949/ccjm.88a.ccc078>
91. Scully M, Singh D, Lown R, Poles A, Solomon T, Levi M et al (2021) Pathologic antibodies to platelet factor 4 after ChAdOx1 nCoV-19 vaccination. *N Engl J Med* 384(23):2202–2211
92. Cines DB, Bussel JB (2021) SARS-CoV-2 vaccine-induced immune thrombotic thrombocytopenia. *Mass Medical Soc*. <https://doi.org/10.1056/NEJMe2106315>
93. Filatov A, Sharma P, Hindi F, Espinosa PS (2020) Neurological complications of coronavirus disease (COVID-19): encephalopathy. *Cureus* 12(3):e7352
94. Vogrig A, Janes F, Gigli GL, Curcio F, Negro ID, D’Agostini S et al (2021) Acute disseminated encephalomyelitis after SARS-CoV-2 vaccination. *Clin Neurol Neurosurg* 208:106839
95. Manzano GS, McEntire CRS, Martinez-Lage M, Mateen FJ, Hutto SK (2021) Acute disseminated encephalomyelitis and acute hemorrhagic leukoencephalitis following covid-19: systematic review and meta-synthesis. *Neurol Neuroimmunol Neuroinflamm*. <https://doi.org/10.1212/NXI.0000000000001080>
96. Utukuri PS, Bautista A, Lignelli A, Moonis G (2020) Possible acute disseminated encephalomyelitis related to severe acute respiratory syndrome coronavirus 2 infection. *AJNR Am J Neuroradiol* 41(9):E82–E83
97. Liu BD, Ugolini C, Jha P (2021) Two cases of post-moderna COVID-19 vaccine encephalopathy associated with nonconvulsive status epilepticus. *Cureus*. <https://doi.org/10.7759/cureus.16172>
98. Cao L, Ren L (2021) Acute disseminated encephalomyelitis after severe acute respiratory syndrome coronavirus 2 vaccination: a case report. *Acta Neurol Belg*. <https://doi.org/10.1007/s13760-021-01608-2>
99. Kenangil GO, Ari BC, Guler C, Demir MK (2021) Acute disseminated encephalomyelitis-like presentation after an inactivated coronavirus vaccine. *Acta Neurol Belg*. <https://doi.org/10.1007/s13760-021-01855-3>
100. Raknuzzaman M, Jannaty T, Hossain MB, Saha B, Dey SK, Shahidullah M (2021) Post covid19 vaccination acute disseminated encephalomyelitis: a case report in bangladesh. *Int J Med Sci Clin Res Stud* 1(03):31–36
101. Byers RK, Moll FC (1948) Encephalopathies following prophylactic pertussis vaccine. *Pediatrics* 1(4):437–457
102. Weibel RE, Caserta V, Benor DE, Evans G (1998) Acute encephalopathy followed by permanent brain injury or death associated with further attenuated measles vaccines: a review of claims submitted to the National vaccine injury compensation program. *Pediatrics* 101(3):383–387



103. Souayah S, Thepmankorn P, Jedidi N, Nasar A, Souayah N. Encephalopathy after Gardasil Vaccination: A Vaccine Adverse Event Reporting System Study 2006–2019 (3038). *Neurology*. 2021;96(15 Supplement):3038.
104. Sugaya N. Influenza-associated encephalopathy in Japan. *Semin Pediatr Infect Dis*. 2002;13(2):79–84.
105. Denholm JT, Neal A, Yan B, Petty S, Knox J, French C et al (2010) Acute encephalomyelitis syndromes associated with H1N1 09 influenza vaccination. *Neurology* 75(24):2246–2248
106. Cavanagh L, Strutt AM, Schulz PE. Acute Demyelinating Encephalomyelitis (ADEM) following rabies vaccination. *International Journal of Case Reports*. 2021 Jun 18;5:206–206.
107. Tourbah A, Gout O, Liblau R, Lyon-Caen O, Boungnot C, Iba-Zizen MT et al (1999) Encephalitis after hepatitis B vaccination: recurrent disseminated encephalitis or MS? *Neurology* 53(2):396–401
108. Baldelli L, Amore G, Montini A, Panzera I, Rossi S, Cortelli P et al (2021) Hyperacute reversible encephalopathy related to cytokine storm following COVID-19 vaccine. *J Neuroimmunol* 358:577661
109. Alnefeesi Y, Siegel A, Lui LMW, Teopiz KM, Ho RCM, Lee Y et al (2020) Impact of SARS-CoV-2 infection on cognitive function: a systematic review. *Front Psychiatry* 11:621773
110. Chahil M, Pillainayagam C, Schulz P. Treatment of Post-Influenza Vaccination Induced Acute Disseminated Encephalomyelitis (ADEM) with Plasma Exchange - A Case Report (P4.036). *Neurology*. 2014;82(10 Supplement):P4.036
111. Iype M, Kunju PAM, Saradakutty G, Anish TS, Sreedharan M, Ahamed SM (2017) Short term outcome of ADEM: results from a retrospective cohort study from South India. *Mult Scler Relat Disord* 18:128–134
112. Ebrahimpour S, Mohseni Afshar Z, Mohseni S, Masrour-Roudsari J, Oladzade S, Bayani M et al (2020) Neurologic manifestations in patients with COVID-19: a case report. *Caspian J Intern Med* 11(Suppl 1):557–560
113. Habib MB, Hamad MK, Kalash T, Ahmed A, Mohamed MF (2021) COVID-19 Pneumonia complicated by seizure due to severe hyponatremia. *Cureus*. <https://doi.org/10.7759/cureus.15603>
114. Fasano A, Cavallieri F, Canali E, Valzania F (2020) First motor seizure as presenting symptom of SARS-CoV-2 infection. *Neurol Sci* 41:1651–1653
115. Marchetti RL, Gallucci-Neto J, Kurcgañ D, Proença ICGF, Valiengo LdCL, Fiore LA et al (2020) Immunization stress-related responses presenting as psychogenic non-epileptic seizures following HPV vaccination in Rio Branco, Brazil. *Vaccine*. 38(43):6714–6720
116. Lin CY, Peng CC, Liu HC, Chiu NC (2011) Psychogenic movement disorder after H1N1 influenza vaccination. *J Neuropsychiatry Clin Neurosci* 23(3):E37–E38
117. Ma SJ, Xiong YQ, Jiang LN, Chen Q (2015) Risk of febrile seizure after measles-mumps-rubella-varicella vaccine: a systematic review and meta-analysis. *Vaccine* 33(31):3636–3649
118. Ghosh R, Dubey S, Roy D, Mandal A, Naga D, Benito-Leon J (2021) Focal onset non-motor seizure following COVID-19 vaccination: a mere coincidence? *Diabetes Metab Syndr* 15(3):1023–1024
119. Aladdin Y, Shirah B (2021) New-onset refractory status epilepticus following the ChAdOx1 nCoV-19 vaccine. *J Neuroimmunol* 357:577629
120. Gavvala JR, Schuele SU (2016) New-onset seizure in adults and adolescents: a review. *JAMA* 316(24):2657–2668
121. Brambilla L, Maronese CA, Toulraki A, Veraldi S (2020) Herpes zoster following COVID-19: a report of three cases. *Eur J Dermatol* 30(6):754–756
122. Saati A, Al-Husayni F, Malibari AA, Bogari AA, Alharbi M (2020) Herpes Zoster co-Infection in an immunocompetent patient with COVID-19. *Cureus* 12(7):e8998
123. Tartari F, Spadotto A, Zengarini C, Zanoni R, Guglielmo A, Adorno A et al (2020) Herpes zoster in COVID-19-positive patients. *Int J Dermatol* 59(8):1028–1029
124. Ruder H, Kerling F, Daniel V, Korn K, Wassmuth R (1995) Decreased alloreactivity after vaccination against hepatitis B. *Transplantation* 59(9):1339–1342
125. Bostan E, Yalici-Armagan B (2021) Herpes zoster following inactivated COVID-19 vaccine: a coexistence or coincidence? *J Cosmet Dermatol* 20(6):1566–1567
126. Bayas JM, Gonzalez-Alvarez R, Guinovart C (2007) Herpes zoster after yellow fever vaccination. *J Travel Med* 14(1):65–66
127. Walter R, Hartmann K, Fleisch F, Reinhard WH, Kuhn M (1999) Reactivation of herpesvirus infections after vaccinations? *Lancet* 353(9155):810
128. Furer V, Zisman D, Kibari A, Rimar D, Paran Y, Elkayam O. Herpes zoster following BNT162b2 mRNA Covid-19 vaccination in patients with autoimmune inflammatory rheumatic diseases: a case series. *Rheumatology* (Oxford, England). 2021
129. van Dam CS, Lede I, Schaar J, Al-Dulaimy M, Rosken R, Smits M (2021) Herpes zoster after COVID vaccination. *Int J Infect Dis* 111:169–171
130. Channa L, Torre K, Rothe M (2021) Herpes zoster reactivation after mRNA-1273 (Moderna) SARS-CoV-2 vaccination. *JAAD Case Rep* 15:60–61
131. Vastarella M, Picone V, Martora F, Fabbrocini G. Herpes zoster after ChAdOx1 nCoV-19 vaccine: a case series. *J Eur Acad Dermatol Venereol*. 2021 Dec;35(12):e845–e846.
132. Arora P, Sardana K, Mathachan SR, Malhotra P. Herpes zoster after inactivated COVID-19 vaccine: A cutaneous adverse effect of the vaccine. *J Cosmet Dermatol*. 2021 Nov;20(11):3389–3390.
133. Chiu HH, Wei KC, Chen A, Wang WH. Herpes zoster following COVID-19 vaccine: A report of three cases. *QJM: An International Journal of Medicine*. 2021 Jul;114(7):531–2.
134. Nastro F, Fabbrocini G, di Vico F, Marasca C (2021) Small vessel vasculitis related to varicella-zoster virus after Pfizer-BioNTech COVID-19 vaccine. *J Eur Acad Dermatol Venereol* 35(11):e745–e747
135. Cohen JI (2013) Clinical practice: Herpes zoster. *N Engl J Med* 369(3):255–263
136. Li X, Ostropelets A, Makadia R, Shaoibi A, Rao G, Sena AG, et al. 2021 Characterizing the incidence of adverse events of special interest for COVID-19 vaccines across eight countries: a multinational network cohort study. *medRxiv*. 22: 553
137. Tagliaferri AR, Narvaneni S, Azzam MH, Grist W (2021) A case of COVID-19 vaccine causing a myasthenia gravis crisis. *Cureus* 13(6):e15581
138. Alfishawy M, Bitar Z, Elgazzar A, Elzouairy M (2021) Neuroleptic malignant syndrome following COVID-19 vaccination. *Am J Emerg Med*. <https://doi.org/10.1016/j.ajem.2021.02.011>
139. Waheed W, Carey ME, Tandan SR, Tandan R (2021) Post COVID-19 vaccine small fiber neuropathy. *Muscle Nerve* 64(1):E1–E2
140. Wan EYF, Chui CSL, Lai FTT, Chan EWY, Li X, Yan VKC et al (2022) Bell's palsy following vaccination with mRNA (BNT162b2) and inactivated (CoronaVac) SARS-CoV-2 vaccines: a case series and nested case-control study. *Lancet Infect Dis* 22(1):64–72
141. Kim JE, Min YG, Shin JY, Kwon YN, Bae JS, Sung JJ et al (2021) Guillain-Barré Syndrome and variants following covid-19 vaccination: report of 13 cases. *Front Neurol* 12:820723
142. Khan E, Shrestha AK, Colantonio MA, Liberio RN, Sriwastava S (2022) Acute transverse myelitis following SARS-CoV-2

- vaccination: a case report and review of literature. *J Neurol* 269(3):1121–1132
143. Huang YJ, Huang CS. 2022 Postvaccinal Encephalopathy Presenting with Amnesia and Seizure After ChAdOx1 nCov-19 Vaccination: A Case Report. *Acta Neurol Taiwan*
  144. Afshar ZM, Babazadeh A, Afsharian M, Vaziri S, Ebrahimpour S (2021) Bell's palsy associated with covid-19 infection: a case report. *Oman Med J* 36(5):e313
  145. Dahl EH, Mosevoll KA, Cramariuc D, Vedeler CA, Blomberg B (2021) COVID-19 myocarditis and postinfection Bell's palsy. *BMJ Case Rep* 14(1):e240095
  146. Bastola A, Sah R, Nepal G, Gajurel BP, Rajbhandari SK, Chalise BS et al (2021) Bell's palsy as a possible neurological complication of COVID-19: a case report. *Clin Case Rep* 9(2):747–750
  147. Al-Mashdali AF, Al Samawi MS (2021) A case of post COVID-19 multisystem inflammatory syndrome and Bell's palsy in a young adult. *Clin Case Rep* 9(9):e04801
  148. Hasibi M, Seyed Ahadi M, Abdollahi H, Jafari M (2021) Protracted COVID-19 during treatment of facial palsy. *Case Rep Neurol Med* 2021:5569841
  149. Ferreira EF, Portugal D, Silva N, Peixoto C, Matos C, Pereira I et al (2022) Rehabilitation of peripheral facial palsy associated with COVID-19 in a child: a case report. *Ann Phys Rehabil Med* 65(1):101600
  150. Iacono A, Pennisi E, Benincasa C, Marchetti F (2022) A case of facial nerve palsy in a pediatric patient associated with Covid-19. *Ital J Pediatr* 48(1):75
  151. Kaplan AC (2021) Noteworthy neurological manifestations associated with covid-19 infection. *Cureus* 13(4):e14391
  152. Szweczyk AK, Skrobas U, Jamroz-Wisniewska A, Mitosek-Szweczyk K, Rejdak K (2021) Facial diplegia-complication or manifestation of SARS-cov-2 Infection? a Case report and systemic literature review. *Healthcare (Basel)*. 9(11):1492
  153. Kumar V, Narayanan P, Shetty S, Mohammed AP (2021) Lower motor neuron facial palsy in a postnatal mother with COVID-19. *BMJ Case Rep* 14(3):e240267
  154. Neo WL, Ng JCF, Iyer NG (2021) The great pretender-Bell's palsy secondary to SARS-CoV-2? *Clin Case Rep* 9(3):1175–1177
  155. Khaja M, Gomez GPR, Santana Y, Hernandez N, Haider A, Lara JLP et al (2020) A 44-year-old Hispanic man with loss of taste and bilateral facial weakness diagnosed with Guillain-Barre syndrome and bell's palsy associated with sars-cov-2 infection treated with intravenous immunoglobulin. *Am J Case Rep* 21:e927956
  156. Theophanous C, Santoro JD, Itani R (2021) Bell's palsy in a pediatric patient with hyper IgM syndrome and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). *Brain Dev* 43(2):357–359
  157. Yue Wan, Shugang Cao, Qi Fang et al. Coronavirus disease 2019 complicated with Bell's palsy: a case report, 16 April 2020, PREPRINT (Version 1) available at Research Square [<https://doi.org/10.21203/rs.3.rs-23216/v1>]
  158. Bohania N, Ish P, Nune A, Iyengar KP (2021) Cranial neuropathy in COVID-19: a case series and review of literature. *Infez Med* 29(4):609–613
  159. Burrows A, Bartholomew T, Rudd J, Walker D (2021) Sequential contralateral facial nerve palsies following COVID-19 vaccination first and second doses. *BMJ Case Rep* 14(7):e243829
  160. Cellina M, D'Arrigo A, Floridi C, Oliva G, Carrafiello G (2022) Left Bell's palsy following the first dose of mRNA-1273 SARS-CoV-2 vaccine: a case report. *Clin Imaging* 82:1–4
  161. Mussatto CC, Sokol J, Alapati N (2022) Bell's palsy following COVID-19 vaccine administration in HIV+ patient. *Am J Ophthalmol Case Rep* 25:101259
  162. Yu BY, Cen LS, Chen T, Yang TH (2021) Bell's palsy after inactivated COVID-19 vaccination in a patient with history of recurrent Bell's palsy: a case report. *World J Clin Cases* 9(27):8274–8279
  163. Mason MC, Liaqat A, Morrow J, Basso R, Gujrati Y (2021) Bilateral facial nerve palsy and covid-19 vaccination: causation or coincidence? *Cureus* 13(8):e17602
  164. Mirmosayyeb O, Barzegar M, Rezaei M, Baharlouie N, Shaygannejad V (2022) Bell's palsy after Sputnik V COVID-19 (Gam-COVID-Vac) vaccination. *Clin Case Rep* 10(2):e05468
  165. Pothiawala S (2021) Bell's palsy after second dose of moderna covid-19 vaccine: coincidence or causation? *Acta Med Litu* 28(2):298–301
  166. Kundi M, Montgomery S, Mao S, Asghar S (2022) Not all that is droopy post ad26cov2s (jnj) vaccine is bell's palsy: a rare case of isolated dorsal pontine stroke causing ipsilateral complete hemifacial palsy. *Cureus*. 14(3):e23195
  167. Nishizawa Y, Hoshina Y, Baker V (2021) Bell's palsy following the Ad26.COV2.S COVID-19 vaccination. *QJM* 114(9):657–658
  168. Martin-Villares C, Vazquez-Feito A, Gonzalez-Gimeno MJ, de la Nogal-Fernandez B (2022) Bell's palsy following a single dose of mRNA SARS-CoV-2 vaccine: a case report. *J Neurol* 269(1):47–48
  169. Scheidl E, Canseco DD, Hadji-Naumov A, Bereznaï B (2020) Guillain-Barre syndrome during SARS-CoV-2 pandemic: a case report and review of recent literature. *J Peripher Nerv Syst* 25(2):204–207
  170. Bueso T, Montalvan V, Lee J, Gomez J, Ball S, Shoustari A et al (2021) Guillain-Barre Syndrome and COVID-19: a case report. *Clin Neurol Neurosurg* 200:106413
  171. Sedaghat Z, Karimi N (2020) Guillain Barre syndrome associated with COVID-19 infection: a case report. *J Clin Neurosci* 76:233–235
  172. Agosti E, Giorgianni A, D'Amore F, Vinacci G, Balbi S, Locatelli D (2021) Is Guillain-Barre syndrome triggered by SARS-CoV-2? Case report and literature review. *Neurol Sci* 42(2):607–612
  173. Paybast S, Gorji R, Mavandadi S (2020) Guillain-Barre syndrome as a neurological complication of novel covid-19 infection: a case report and review of the literature. *Neurologist* 25(4):101–103
  174. Dufour C, Co TK, Liu A (2021) GM1 ganglioside antibody and COVID-19 related Guillain Barre Syndrome - a case report, systemic review and implication for vaccine development. *Brain Behav Immun Health* 12:100203
  175. Toscano G, Palmerini F, Ravaglia S, Ruiz L, Invernizzi P, Cuzzoni MG et al (2020) Guillain-Barre syndrome associated with SARS-CoV-2. *N Engl J Med* 382(26):2574–2576
  176. El Otmani H, El Moutawakil B, Rafai MA, El Benna N, El Kettani C, Soussi M et al (2020) Covid-19 and Guillain-Barre syndrome: more than a coincidence! *Rev Neurol (Paris)* 176(6):518–519
  177. Khan F, Sharma P, Pandey S, Sharma D, V V, Kumar N, et al (2021) COVID-19-associated Guillain-Barre syndrome: Postinfectious alone or neuroinvasive too? *J Med Virol* 93(10):6045–6049
  178. Su XW, Palka SV, Rao RR, Chen FS, Brackney CR, Cambi F (2020) SARS-CoV-2-associated Guillain-Barre syndrome with dysautonomia. *Muscle Nerve* 62(2):E48–E49
  179. Darvishi M, Shahali H, Farahani AA (2021) Guillain-Barre syndrome associated with sars-cov-2 infection: a case report. *Eur J Transl Myol*. <https://doi.org/10.4081/ejtm.2021.9494>
  180. Zhao H, Shen D, Zhou H, Liu J, Chen S (2020) Guillain-Barre syndrome associated with SARS-CoV-2 infection: causality or coincidence? *Lancet Neurol* 19(5):383–384
  181. Mackenzie N, Lopez-Coronel E, Dau A, Maloof D, Mattar S, Garcia JT et al (2021) Concomitant Guillain-Barre syndrome with COVID-19: a case report. *BMC Neurol* 21(1):135

182. Mostel Z, Ayat P, Capric V, Trimmingham A, McFarlane SI (2021) Guillain-Barre syndrome in a covid-19 patient: a case report and review of management strategies. *Am J Med Case Rep* 9(3):198–200
183. Farzi MA, Ayromlou H, Jahanbakhsh N, Bavil PH, Janzadeh A, Shayan FK (2020) Guillain-Barre syndrome in a patient infected with SARS-CoV-2, a case report. *J Neuroimmunol* 346:577294
184. Nejad JH, Heiat M, Hosseini MJ, Allahyari F, Lashkari A, Torabi R et al (2021) Guillain-Barre syndrome associated with COVID-19: a case report study. *J Neurovirol* 27(5):802–805
185. McKean N, Chircop C (2021) Guillain-Barre syndrome after COVID-19 vaccination. *BMJ Case Rep* 14(7):e244125
186. Hasan T, Khan M, Khan F, Hamza G (2021) Case of Guillain-Barre syndrome following COVID-19 vaccine. *BMJ Case Rep* 14(6):e243629
187. Allen CM, Ramsamy S, Tarr AW, Tighe PJ, Irving WL, Tanasescu R et al (2021) Guillain-Barre syndrome variant occurring after sars-cov-2 vaccination. *Ann Neurol* 90(2):315–318
188. Min YG, Ju W, Ha YE, Ban JJ, Lee SA, Sung JJ et al (2021) Sensory Guillain-Barre syndrome following the ChAdOx1 nCov-19 vaccine: report of two cases and review of literature. *J Neuroimmunol* 359:577691
189. Scendoni R, Petrelli C, Scaloni G, Logullo FO (2021) Electromyoneurography and laboratory findings in a case of Guillain-Barre syndrome after second dose of Pfizer COVID-19 vaccine. *Hum Vaccin Immunother* 17(11):4093–4096
190. Maramattom BV, Krishnan P, Paul R, Padmanabhan S, Cherukudal Vishnu Nampoothiri S, Syed AA et al (2021) Guillain-Barre Syndrome following ChAdOx1-S/nCoV-19 Vaccine. *Ann Neurol* 90(2):312–314
191. Introna A, Caputo F, Santoro C, Guerra T, Ucci M, Mezzapesa DM et al (2021) Guillain-Barre syndrome after AstraZeneca COVID-19-vaccination: a causal or casual association? *Clin Neurol Neurosurg* 208:106887
192. Razok A, Shams A, Almeer A, Zahid M (2021) Post-COVID-19 vaccine Guillain-Barre syndrome; first reported case from Qatar. *Ann Med Surg (Lond)* 67:102540
193. Rao SJ, Khurana S, Murthy G, Dawson ET, Jazebi N, Haas CJ (2021) A case of Guillain-Barre syndrome following Pfizer COVID-19 vaccine. *J Community Hosp Intern Med Perspect* 11(5):597–600
194. Moreno-Escobar MC, Kataria S, Khan E, Subedi R, Tandon M, Peshwe K et al (2021) Acute transverse myelitis with dysautonomia following sars-cov-2 infection: a case report and review of literature. *J Neuroimmunol* 353:577523
195. Qazi R, Memon A, Mohamed AS, Ali M, Singh R (2021) Post-COVID-19 acute transverse myelitis: a case report and literature review. *Cureus* 13(12):e20628
196. Chow CCN, Magnussen J, Ip J, Su Y. 2020 Acute transverse myelitis in COVID-19 infection. *BMJ Case Rep.*:13(8)
197. Sarma D, Bilello LA (2020) A case report of acute transverse myelitis following novel coronavirus infection. *Clin Pract Cases Emerg Med* 4(3):321–323
198. Ahmad SA, Salih KH, Ahmed SF, Kakamad FH, Salh AM, Hassan MN et al (2021) Post COVID-19 transverse myelitis; a case report with review of literature. *Ann Med Surg (Lond)* 69:102749
199. Nejad Biglari H, Sinaei R, Pezeshki S, Khajeh HF (2021) Acute transverse myelitis of childhood due to novel coronavirus disease 2019: The first pediatric case report and review of literature. *Iran J Child Neurol* 15(1):107–112
200. Palahuta HV, Fartushna OY, Yevtushenko SK, Hnepa YY (2021) Acute transverse myelitis as a neurological complication of covid-19: a case report. *Wiad Lek* 74(4):1045–1049
201. Lingas EC (2022) A case of acute transverse myelitis in a mildly symptomatic patient: an emerging and serious neurological manifestation of COVID-19. *Cureus* 14(4):e24222
202. Prete S, McShannic JD, Fertel BS, Simon EL (2022) Acute transverse myelitis progressing to permanent quadriplegia following COVID-19 infection. *Am J Emerg Med* 56(391):e1–e3
203. Shahali H, Ghasemi A, Farahani RH, Nezami Asl A, Hazrati E (2021) Acute transverse myelitis after SARS-CoV-2 infection: a rare complicated case of rapid onset paraplegia. *J Neurovirol* 27(2):354–358
204. Hsiao YT, Tsai MJ, Chen YH, Hsu CF. Acute transverse myelitis after COVID-19 vaccination. *Medicina*. 2021 Sep 25;57(10):1010.
205. Tan WY, Yusof Khan AHK, Mohd Yaakob MN, Abdul Rashid AM, Loh WC, Baharin J et al (2021) Longitudinal extensive transverse myelitis following ChAdOx1 nCOV-19 vaccine: a case report. *BMC Neurol* 21(1):395
206. Notghi AA, Atley J, Silva M (2021) Lessons of the month 1: longitudinal extensive transverse myelitis following astraZeneca covid-19 vaccination. *Clin Med (Lond)* 21(5):e535–e538
207. Eom H, Kim SW, Kim M, Kim YE, Kim JH, Shin HY et al (2022) Case reports of acute transverse myelitis associated with mRNA vaccine for COVID-19. *J Korean Med Sci* 37(7):e52
208. Miyae N, Yoshida A, Yamanishi Y, Tada S, Ando R, Hosokawa Y et al (2022) Refractory longitudinally extensive transverse myelitis after severe acute respiratory syndrome coronavirus 2 vaccination in a Japanese man. *Intern Med* 61(5):739–742
209. Maroufi SF, Naderi Behdani F, Rezaei F, Tanhapour Khotb-ehsara S, Mirzaasgari Z (2022) Longitudinally extensive transverse myelitis after Covid-19 vaccination: case report and review of literature. *Hum Vaccin Immunother* 18(1):2040239
210. Tahir N, Koorapati G, Prasad S, Jeelani HM, Sherchan R, Shrestha J et al (2021) SARS-CoV-2 vaccination-induced transverse myelitis. *Cureus* 13(7):e16624
211. Hirose S, Hara M, Koda K, Natori N, Yokota Y, Ninomiya S et al (2021) Acute autoimmune transverse myelitis following COVID-19 vaccination: a case report. *Medicine (Baltimore)* 100(51):e28423
212. Rajae A, Manal M, Ghizlane EA, Amine B, Zaid I, Houssam B et al (2021) Ischemic stroke revealing covid-19 infection: case report. *Ann Med Surg (Lond)* 71:102912
213. Avvantaggiato C, Amoruso L, Lo Muzio MP, Mimmo MA, Delli Bergoli M, Cinone N et al (2021) Ischemic stroke in a 29-year-old patient with covid-19: a case report. *Case Rep Neurol* 13(2):334–340
214. Bigliardi G, Ciolli L, Giovannini G, Vandelli L, Dell'Acqua ML, Borzi GM et al (2020) Middle cerebral artery ischemic stroke and COVID-19: a case report. *J Neurovirol* 26(6):967–969
215. Zhai P, Ding Y, Li Y (2020) The impact of COVID-19 on ischemic stroke. *Diagn Pathol* 15(1):78
216. Farooque U, Shabih S, Karimi S, Lohano AK, Kataria S (2020) Coronavirus disease 2019-related acute ischemic stroke: a case report. *Cureus* 12(9):e10310
217. Owolabi LF, Raafat A, Enwere OO, Mustapha AF, Adamu B, AlGhamdi M (2021) Hemorrhagic infarctive stroke in COVID-19 patients: report of two cases and review of the literature. *J Community Hosp Intern Med Perspect* 11(3):322–326
218. Fraiman P, Freire M, Moreira-Neto M, Godeiro-Junior C (2020) Hemorrhagic stroke and COVID-19 infection: coincidence or causality. *eNeurologicalSci*. <https://doi.org/10.1016/j.ensci.2020.100274>
219. Flores G, Kumar JI, Pressman E, Sack J, Alikhani P (2020) Spontaneous brainstem hemorrhagic stroke in the setting of novel coronavirus disease 2019 - a case report. *Cureus* 12(10):e10809



220. Dakay K, Cooper J, Bloomfield J, Overby P, Mayer SA, Nuoman R et al (2021) Cerebral venous sinus thrombosis in COVID-19 Infection: a case series and review of the literature. *J Stroke Cerebrovasc Dis* 30(1):105434
221. Anipindi M, Scott A, Joyce L, Wali S, Morginstin M (2021) Case report: cerebral venous sinus thrombosis and COVID-19 infection. *Front Med (Lausanne)* 8:741594
222. Tu TM, Goh C, Tan YK, Leow AS, Pang YZ, Chien J et al (2020) Cerebral venous thrombosis in patients with COVID-19 infection: a case series and systematic review. *J Stroke Cerebrovasc Dis* 29(12):105379
223. Elaidouni G, Chetouani Z, Manal Merbouh CB, Bkiyar H, Housni B (2022) Acute ischemic stroke after first dose of inactivated COVID-19 vaccine: a case report. *Radiol Case Rep* 17(6):1942–1945
224. Kenda J, Lovric D, Skerget M, Milivojevic N (2021) Treatment of ChAdOx1 nCoV-19 vaccine-induced immune thrombotic thrombocytopenia related acute ischemic stroke. *J Stroke Cerebrovasc Dis* 30(11):106072
225. Al-Mayhani T, Saber S, Stubbs MJ, Losseff NA, Perry RJ, Simister RJ et al (2021) Ischaemic stroke as a presenting feature of ChAdOx1 nCoV-19 vaccine-induced immune thrombotic thrombocytopenia. *J Neurol Neurosurg Psychiatry* 92(11):1247–1248
226. de Melo Silva ML, Jr., Lopes DP. (2021) Large hemorrhagic stroke after ChAdOx1 nCoV-19 vaccination: a case report. *Acta Neurol Scand* 144(6):717–718
227. Takeyama R, Fukuda K, Kouzaki Y, Koga T, Hayashi S, Ohtani H et al (2022) Intracerebral hemorrhage due to vasculitis following COVID-19 vaccination: a case report. *Acta Neurochir* 164(2):543–547
228. Dias L, Soares-Dos-Reis R, Meira J, Ferrao D, Soares PR, Pastor A et al (2021) Cerebral venous thrombosis after BNT162b2 mRNA SARS-CoV-2 vaccine. *J Stroke Cerebrovasc Dis* 30(8):105906
229. Zakaria Z, Sapiai NA, Ghani ARI (2021) Cerebral venous sinus thrombosis 2 weeks after the first dose of mRNA SARS-CoV-2 vaccine. *Acta Neurochir (Wien)* 163(8):2359–2362
230. D'Agostino V, Caranci F, Negro A, Piscitelli V, Tuccillo B, Fasano F et al (2021) A rare case of cerebral venous thrombosis and disseminated intravascular coagulation temporally associated to the COVID-19 vaccine administration. *J Pers Med* 11(4):285
231. Atta SN, Othman N, Babar M (2021) Cerebral venous sinus thrombosis secondary to ChAdOx-1 nCov-19 vaccine. *BMJ Case Rep*. <https://doi.org/10.1136/bcr-2021-246200>
232. Delorme C, Paccoud O, Kas A, Hesters A, Bombois S, Shambrook P et al (2020) COVID-19-related encephalopathy: a case series with brain FDG-positron-emission tomography/computed tomography findings. *Eur J Neurol* 27(12):2651–2657
233. Lazraq M, Benhamza S, Saadaoui S, Hayar S, Louardi M, Moujahid H et al (2021) Encephalopathy and COVID-19: a case report. *Pan Afr Med J* 38:139
234. Goodloe TB 3rd, Walter LA (2021) COVID-19 presenting as encephalopathy in the emergency department: a case report. *Clin Pract Cases Emerg Med* 5(1):26–29
235. Teimouri-Jervekani Z, Salmasi M (2021) Presentation of COVID-19 infection with bizarre behavior and encephalopathy: a case report. *J Med Case Rep* 15(1):220
236. Al-Mashdali AF, Ata YM, Sadik N (2021) Post-COVID-19 vaccine acute hyperactive encephalopathy with dramatic response to methylprednisolone: a case report. *Ann Med Surg (Lond)* 69:102803
237. Liu BD, Ugolini C, Jha P (2021) Two Cases of Post-Moderna COVID-19 Vaccine Encephalopathy Associated With Nonconvulsive Status Epilepticus. *Cureus* 13(7):e16172
238. Bensaidane MR, Picher-Martel V, Emond F, De Serres G, Dupre N, Beauchemin P (2022) Case report: acute necrotizing encephalopathy following COVID-19 vaccine. *Front Neurol* 13:872734
239. Monti G, Giovannini G, Marudi A, Bedin R, Melegari A, Simone AM et al (2020) Anti-NMDA receptor encephalitis presenting as new onset refractory status epilepticus in COVID-19. *Seizure* 81:18–20
240. Bhatta S, Sayed A, Ranabhat B, Bhatta RK, Acharya Y (2020) New-onset seizure as the only presentation in a child with COVID-19. *Cureus* 12(6):e8820
241. Park S, Majoka H, Sheikh A, Ali I (2021) A presumed case of new-onset focal seizures as a delayed complication of COVID-19 infection. *Epilepsy Behav Rep* 16:100447
242. Dono F, Carrarini C, Russo M, De Angelis MV, Anzellotti F, Onofri M et al (2021) New-onset refractory status epilepticus (NORSE) in post SARS-CoV-2 autoimmune encephalitis: a case report. *Neurol Sci* 42(1):35–38
243. Cho YJ, Kim HK (2022) New-onset seizures in patients with COVID-19: A case series from a single public hospital in Korea. *J Korean Med Sci* 37(12):e97
244. Bauman K, Rosenthal J, Lin J. New-Onset Refractory Status Epilepticus After Pfizer-BioNTech COVID-19 Vaccination (P3-8.006). *Neurology*. 2022;98(18 Supplement):3631.
245. Desai HD, Sharma K, Patoliya JV, Ahadov E, Patel NN (2021) A rare case of Varicella-Zoster virus reactivation following recovery from COVID-19. *Cureus* 13(1):e12423
246. Saleh W, Ata F, Elashry MM (2021) Is COVID-19 infection triggering oral herpes zoster? A case report. *SAGE Open Med Case Rep*. <https://doi.org/10.1177/2050313X211065793>
247. van Dam CS, Lede I, Schaar J, Al-Dulaimy M, Rösken R, Smits M (2021) Herpes zoster after COVID vaccination. *Int J Infect Dis* 111:169–171
248. Rodriguez-Jimenez P, Chicharro P, Cabrera LM, Segui M, Morales-Caballero A, Llamas-Velasco M et al (2021) Varicella-zoster virus reactivation after SARS-CoV-2 BNT162b2 mRNA vaccination: report of 5 cases. *JAAD Case Rep* 12:58–59
249. Santovito LS, Pinna G (2021) A case of reactivation of varicella-zoster virus after BNT162b2 vaccine second dose? *Inflamm Res* 70(9):935–937

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